THE UNIVERSITY OF ALBERTA

ANALYSIS OF THE TENSILE SPLITTING TEST FOR LOW TEMPERATURE TENSILE PROPERTIES OF ASPHALTIC CONCRETE

by

© RALPH HAROLD ALTON CHRISTIANSON

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF CIVIL ENGINEERING

EDMONTON, ALBERTA

SPRING, 1970

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled

ANALYSIS OF THE TENSILE SPLITTING TEST

FOR LOW TEMPERATURE TENSILE

PROPERTIES OF ASPHALTIC CONCRETE

submitted by Ralph Harold Alton Christianson

in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The primary objective of this thesis was to develop a computer analysis method to facilitate the analysis of the tensile splitting test for low temperature tensile properties of asphaltic concrete. The computer programs developed within this thesis were used to analyze the results of the tensile splitting test for cored pavement specimens obtained during the early service life of a four-lane divided freeway in central Alberta. In addition, an analysis of alternate laboratory preparation methods, and a preliminary investigation into the effect of density upon the low temperature tensile properties of asphaltic concrete were undertaken within the scope of this thesis.

The tensile splitting test method consists of loading a 4 - inch diameter asphalt concrete cylinder via loading strips across a diameter, in a compression testing frame and within a controlled temperature chamber maintained at a constant low temperature. Output signals from a load cell and two series connected linear variable differential transformers (attached to opposite ends of the specimen) are monitored on a two channel recorder.

Five computer programs were established to analyze

the tensile splitting test results. The programs vary from the basic analysis of computed parameters measured throughout the duration of the test, to the Calcomp plots of stress versus strain and stiffness versus strain for all the test specimens within a test series.

The results of the analysis of the highway test project indicated a definite correlation between the low temperature transverse cracking of asphalt pavements, and the failure stress, failure strain, and failure stiffness of the asphaltic concrete as measured by the tensile splitting test at 0°F. The analysis of the alternate laboratory specimen preparation methods indicated that the 75 blow impact compaction yields a density equivalent to that obtained by kneading compaction. Furthermore, a decrease in the density reduces the failure stress and failure stiffness, but increases the magnitude of the failure strain.

The principal conclusion from this research is that the established computer programs permit a thorough study of the low temperature tensile properties of asphaltic concrete. The major recommendation from this study, is that, in the design and evaluation of asphalt pavements, subjected to low temperatures, the tensile splitting test and analysis methods should be adopted to determine the low temperature tensile characteristics of the asphaltic concrete.

ACKNOWLEDGEMENTS

The author extends his sincere thanks to the following:

K.O. Anderson, Associate Professor of Civil Engineering, University of Alberta, for his guidance of this thesis program.

The Alberta Department of Highways for asphaltic concrete cored specimens and pertinent data.

The Research Council of Alberta, The Highway and River Engineering Division, for pertinent data and assistance throughout this research program.

The National Research Council for partial support under Research Grant A2139.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Low temperature transverse cracking of asphaltic concrete pavement surfaces has been under intensive study during recent years. Agencies involved in the design, testing and evaluation of pavement components for use in areas having a significant amount of sub-freezing weather, have recognized that the development of transverse cracks may lead to a rapid loss in pavement serviceability. In order to determine the relative susceptibility of a pavement to low temperature transverse cracking, the majority of the research has involved tests on the asphalt cement and/or the asphaltic concrete under various service and laboratory conditions.

STATE OF INVESTIGATIONS

This thesis is one of a series of continuing research programs at The University of Alberta concerned with the low temperature tensile properties of asphalt cement and asphalt concrete cylinders. The previous research conducted by Gillespie (1966), Christison (1966) and Hahn (1967) involved the development of a laboratory test, to be used at the mix design stage, for predicting

the cracking behavior of a given asphalt concrete pavement. This test method has been described in detail by Anderson and Hahn (1968). The research work conducted within the scope of this thesis involved refinements of the testing technique as well as the establishment of computer programs for the analysis of the tensile splitting test results. In addition, the thesis includes the further application of the tensile splitting test to field cores at various temperatures and ages for different asphalt supplies, as well as laboratory specimens prepared by both kneading and impact compaction methods and tested at various temperatures and compactive efforts.

OBJECTIVES OF THE THESIS

From the results of the initial investigations of the use of the tensile splitting test for asphaltic concrete, further investigation was warranted and the primary objective of this research was to develop a computer analysis program or series of programs to facilitate the analysis of test results to establish parameters for the low temperature tensile properties of asphaltic concrete.

Secondary objectives of this research were as follows:

1. To use the established program or series of programs to demonstrate the trends in the low temperature tensile properties and cracking frequency during the early service life of a particular highway pavement.

2. To conduct an analytical comparison of alternate laboratory specimen preparation methods (i.e., kneading and impact compaction) in order to determine characteristic properties as well as low temperature tensile properties of the asphaltic concrete.
3. To conduct a preliminary analysis to determine the effect of compaction upon the low temperature tensile properties of asphaltic concrete.

LIMITATIONS OF THE THESIS

Some of the more significant limitations of this thesis are:

1. Inherent difficulties of using the tensile splitting test for asphalt concrete cylinders which respond, at the rate of loading used, as a visco-elastic material.
2. The use of only one rate of loading in the testing program.
3. The variations in material placed under construction or field conditions.
4. The investigation does not attempt to explain the behavior of the asphalt concrete cylinders in terms of the properties of the binder.

ORGANIZATION OF THE THESIS

Chapter II provides a description of the test method and analysis of the tensile splitting test as applied to asphalt concrete cylinders. It also includes a brief review of the development and previous work with the tensile splitting test at The University of Alberta, as well as a brief description of the computer programs developed to facilitate the analysis of the tensile splitting test to establish parameters for the low temperature tensile properties of asphaltic concrete.

Chapter III is devoted to the application of test results. It provides an example of how the analysis programs may be used to establish trends of low temperature tensile properties and cracking frequency on a four-lane divided freeway facility in central Alberta. In also includes a brief discussion of the methods used to compare the characteristic properties, as well as the low temperature tensile properites, of laboratory specimens prepared by kneading and impact compaction. In addition, there is a brief summary of the preliminary investigation into determining the effect of compaction upon the low temperature tensile properties of asphaltic concrete.

Chapter IV contains the conclusions drawn from this investigation, the recommendations presented as a result of this investigation, and the recommendations for further study.

CHAPTER II

TEST METHODS AND ANALYSIS

This thesis is one of a series of continuing research programs at The University of Alberta, concerned with the low temperature tensile properties of asphalt cement and asphalt concrete cylinders. Previous authors, Gillespie (1966), Christison (1966) and Hahn (1967) have presented extensive reviews of work done on the tensile behavior of asphalt cement and asphaltic concrete, and therefore a literature review will not be repeated in this report. The information provided within this chapter only provides a brief review of the main points of the tensile splitting test, noting any revisions, along with a brief description of the computer programs established for the analysis of the tensile splitting test results.

TENSILE SPLITTING TEST

The theory involved in the tensile splitting test is described in reports by Gillespie (1966), Christison (1966) and Hahn (1967). The method of test, materials, and apparatus are described in detail in Appendix A, Sections 1.1 to 6.4.4.

Briefly, the tensile splitting test consists of loading a 4 - inch diameter asphalt concrete cylinder via loading strips across a diameter, in a compression testing

frame and within a controlled temperature chamber maintained at a constant low temperature. Output signals from a load cell and two series connected linear variable differential transformers (attached to opposite ends of the specimen) are monitored on a two channel recorder. The analysis of the results from the tensile splitting test may vary from the simplest analysis as outlined in Appendix A, Section 7.1., to one of the computer analysis methods described in this chapter.

DEVELOPMENT OF COMPUTER PROGRAMS

In previous work by Hahn (1967) the output signals were monitored on an X-Y plotter. The load and strain coordinates for each specimen, within a test series, were then supplied as input for a computer program to compute and tabulate the coordinates of the average stress-strain curve for that test series.

The emphasis placed upon the use of the computer for the analysis of the tensile splitting test is based upon the improvements that may be realized in the data interpreation. In the initial stages of this research, the computer program was established for use on The University of Alberta IBM 360-67, to output sufficient data to identify the test specimen, and to list computed values of the various parameters at several stages throughout the tensile splitting test. The next major revision in the computer analysis involved changes so that a statistical summary of all

properties and computed parameters would be available at the completion of the analysis of the last specimen within a test series. The final stage of the computer analysis development involved the establishment of programs to permit computer plotting of various parameters with the use of The University of Alberta Calcomp Plotter, model 770/663.

Five computer programs are included within the report and are described in detail in Appendix A. The following section is included to serve only as a guide to the use of the various programs and is therefore brief in nature.

BRIEF DESCRIPTION OF COMPUTER PROGRAMS

All programs are established so that the printed output comprises one page per specimen, followed by a statistical summary for the complete test series. The single page for each specimen includes a summary of the properties and identification of the test specimen, as well as various computed parameters at several stages throughout the tensile splitting test. The statistical summary includes the mean, standard deviation and coefficient of variation of various parameters within the test series.

BASIC COMPUTER ANALYSIS

In order to use the "Basic Computer Analysis" for the tensile splitting test the only details required are the geometry of the test specimen and the load-deformation

trace from the two channel recorder. The parameters considered within the output of this program are the stress, strain, stiffness of mix and time.

STRESS is the tensile stress in pounds per square inch computed using a formula based on the theory of elasticity. STRAIN is the horizontal strain, in inches per inch, due to the biaxial stress condition. STIFFNESS OF MIX is the stiffness, in pounds per square inch, computed by considering the ratio of the tensile stress to the tensile strain computed with an assumed Poisson's ratio of 0.33. TIME is the elapsed time, in seconds, from "zero time" to any stage within the execution of the tensile splitting test. "Zero time" is arbitrarily established as that point where the plywood loading strips have compressed sufficiently to allow a uniform load application upon the specimen (See Appendix A, Section 7.2.7.). The "Basic Computer Analysis" program is described in detail in Appendix A, Section 7.3.

A sample output for the results of one specimen analyzed by the "Basic Computer Analysis" program is provided in FIGURE 2.1. In addition, a sample statistical summary from the "Basic Computer Analysis" program is provided in FIGURE 2.2.

DETAILED COMPUTER ANALYSIS

If data are available to determine the volumetric

relationships of the constituents, the "Detailed Computer Analysis" program may be used. The program is intended for analysis of test results in a manner similar to Heukolom (1966) involving the stiffness of bitumen and the stiffness of mix. Furthermore, the analysis involves the determination of the toughness, i.e. the area under the stress-strain curve, as well as the determination of the work input per unit volume using the work-energy concept (Breen and Stephens, 1966). The "Detailed Computer Analysis" program is described in detail in Appendix A, Section 7.4.

A sample output for the results of one specimen analyzed by the "Detailed Computer Analysis" program is provided in FIGURE 2.3. In addition a sample statistical summary from the "Detailed Computer Analysis" program is provided in FIGURE 2.4.

COMPUTER ANALYSIS WITH STRESS-STRAIN PLOT

The printed output for this program is the same as that for the "Basic Computer Analysis"; but the additional information is provided in the form of an 8-1/2 by 11 - inch plot of stress versus strain for all the specimens within a test series plotted on a single graph. This program is described in detail in Appendix A, Section 7.5.

A sample plot from the "Computer Analysis with Stress-Strain Plot" program is provided in FIGURE 2.5.

COMPUTER ANALYSIS WITH STIFFNESS-STRAIN PLOT

The output for this program is similar to the "Computer Analysis with Stress-Strain Plot" except for the fact that the plot will be stiffness of mix versus strain for the complete test series. This program is described in detail in Appendix A, Section 7.6.

A sample plot from the "Computer Analysis with Stiffness-Strain Plot" program is provided in FIGURE 2.6.

COMPUTER ANALYSIS WITH STRESS-STRAIN AND STIFFNESS-STRAIN PLOTS

This program allows a printed output as previously described, as well as a plot of stress versus strain adjacent to a plot of stiffness of mix versus strain for the same test series. For convenience of plotting, and also to allow valuable comparisons, two such combinations are plotted on a 17 by 22 - inch plot. Samples of this form of output, to a reduced scale, are given in Appendices B, C & D. This program is described in detail in Appendix A, Section 7.7.

A sample plot from the "Computer Analysis with Stress-Strain and Stiffness-Strain Plots" program is provided in FIGURE 2.7.

SUPPLY NUMBER 5268 & WATSONVILLE AGG.   COMPACTION : 75 BLOWS

PAGE 1 OF 7

SAMPLE NUMBER : SM 21

BULK SPECIFIC GRAVITY OF THE COMPACTED MIXTURE = 2.443

UNIT WEIGHT = 152.4 POUNDS PER CUBIC FOOT

DIAMETER = 4.005 INCHES

THICKNESS = 2.521 INCHES

DETAILS OF TEST

RATE OF LOADING = 0.056 INCHES / MINUTE   TIME TO FRACTURE = 161 SECONDS

TEST TEMPERATURE : 0 DEGREES FAHRENHEIT   DATE : MAY 1 , 1969

STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)
182.85	0.000100	3335248	95
277.43	0.000200	2530187	120
302.65	0.000300	1840135	138
378.32	0.000400	1725129	150
416.15	0.000500	1518113	155
441.37	0.001000	805059	161

FIGURE 2.1 Sample Output for The Results of One Specimen Analyzed by the "Basic Computer Analysis" Program.

SUPPLY NUMBER 5268 & WATSONVILLE AGG. COMPACTION : 75 BLOWS

PAGE 7 OF 7

MEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION
FOR
THE 5 SAMPLES IN THIS SERIES
BASED UPON FAILURE CONDITIONS

SAMPLE NUMBERS : SM 21 SM 22 SM 23 SM 24 SM 25

TEST TEMPERATURE : 0 DEGREES FAHRENHEIT DATE : MAY 1 , 1969

	STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)	UNIT WEIGHT (P.C.F.)
MEAN	543.67	0.001160	859114	193.0	153.34
STANDARD DEVIATION	67.83	0.000152	97718	24.9	0.95
COEFFICIENT OF VARIATION (%)	12.48	13.07	11.37	12.92	0.62

FIGURE 2.2 Sample Statistical Summary From the "Basic Computer Analysis" Program

SUPPLY NUMBER 5268 & WATSONVILLE AGG. COMPACTION : 75 BLOWS

PAGE 1 OF 7

SAMPLE NUMBER : SM 21 TEST TEMPERATURE : 0 DEGREES FAHRENHEIT DATE : MAY 1 , 1969

DIAMETER = 4.005 INCHES THICKNESS = 2.521 INCHES

ASPHALT CONTENT OF THE MIX = 6.00 % SP. GR. OF THE AGGREGATE = 2.840 SP. GR. OF THE ASPHALT = 1.010

ASPHALT ABSORPTION = 0.0 % EFFECTIVE ASPHALT CONTENT OF THE MIX = 6.00 %

BULK SP. GR. OF THE COMPACTED MIXTURE = 2.443 UNIT WEIGHT = 152.4 P.C.F. AIR VOIDS = 5.17 %

VOLUME CONCENTRATION OF AGGREGATE = 0.856 VOLUME CONCENTRATION OF BITUMEN = 0.144

RATE OF LOADING = 0.056 INCHES / MINUTE TIME TO FRACTURE = 161 SECONDS

STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)	STIFFNESS OF BITUMEN (PSI)	STIFFNESS OF BITUMEN (KG/SQ CM)	BITUMEN STRAIN (IN/IN)	TOUGHNESS (PSI)	WORK INPUT PER UNIT VOLUME (IN-LB/CU IN)
182.85	0.00010	3335248	95	141581	9956	0.00069	0.0091	4.86
277.43	0.00020	2530187	120	80796	5681	0.00139	0.0322	8.08
302.65	0.00030	1840135	138	44284	3114	0.00208	0.0612	11.01
378.32	0.00040	1725129	150	39498	2777	0.00277	0.0952	13.29
416.15	0.00050	1518113	156	31594	2221	0.00346	0.1349	14.63
441.37	0.00100	805059	161	10907	767	0.00693	0.3493	15.83

FIGURE 2.3 Sample Output for the Results of One Specimen Analyzed bt the "Detailed Computer Analysis" Program

SUPPLY NUMBER 5268 & WATSONVILLE AGG. COMPACTION : 75 BLOWS

PAGE 7 OF 7

MEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION
FOR
THE 5 SAMPLES IN THIS SERIES
BASED UPON FAILURE CONDITIONS

SAMPLE NUMBERS : SM 21 SM 22 SM 23 SM 24 SM 25

TEST TEMPERATURE : 0 DEGREES FAHRENHEIT DATE : MAY 1 , 1969

	STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)	UNIT WEIGHT (P.C.F.)	AIR VOIDS (%)
MEAN	543.67	0.001160	859114	193.0	153.34	4.60
STANDARD DEVIATION	67.83	0.000152	97718	24.9	0.95	0.59
COEFFICIENT OF VARIATION (%)	12.48	13.07	11.37	12.92	0.62	12.92

	TOUGHNESS (PSI)	BITUMEN STRAIN (IN/IN)	STIFFNESS OF BITUMEN (KG/SQ CM)	WORK INPUT PER UNIT VOLUME (IN-LB/CU IN)
MEAN	0.4798	0.008036	764	21.19
STANDARD DEVIATION	0.1173	0.001051	110	3.94
COEFFICIENT OF VARIATION (%)	24.44	13.07	14.44	18.61

FIGURE 2.4 Sample Statistical Summary from the "Detailed Computer Analysis" Program

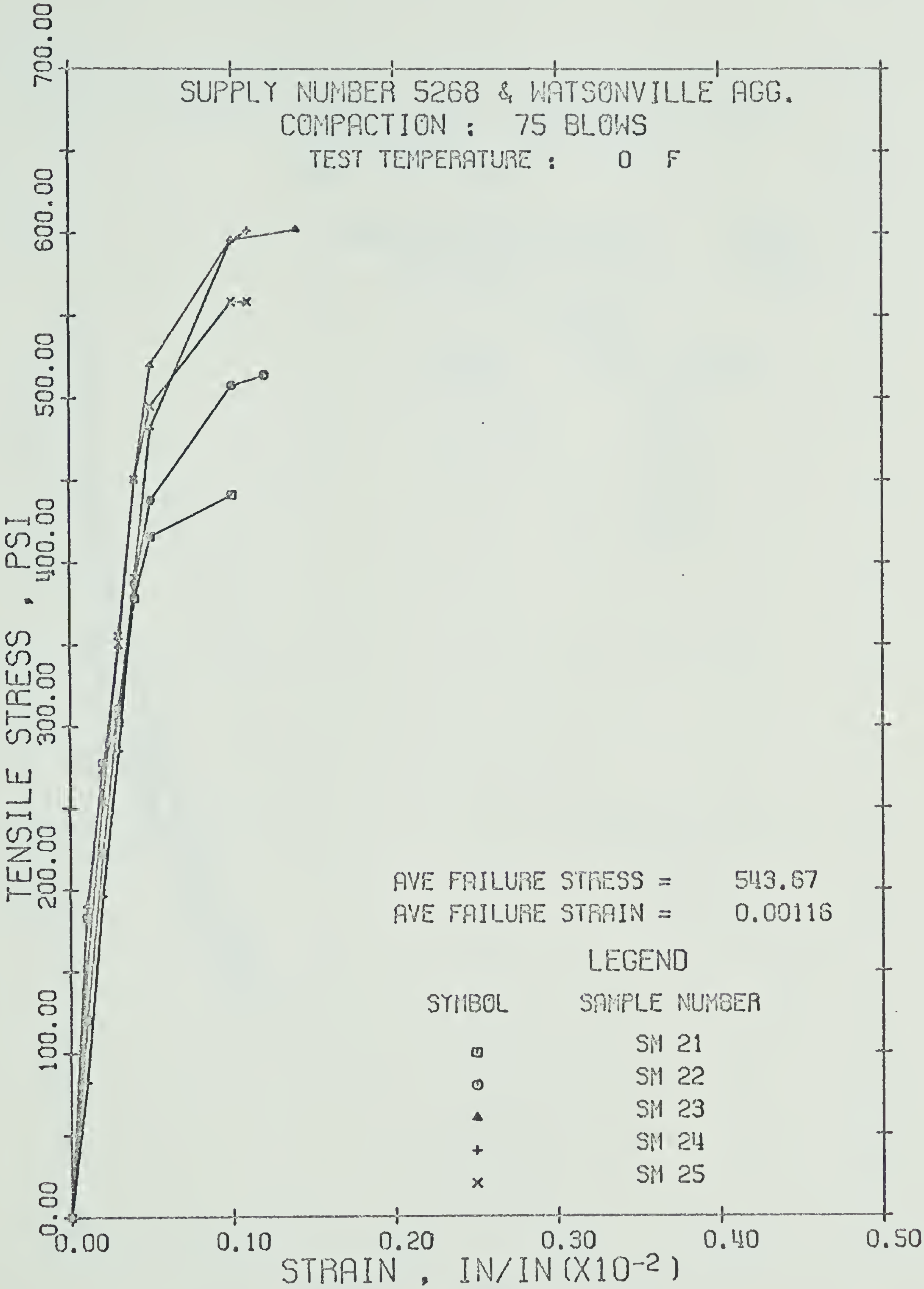


FIGURE 2.5 Sample Plot from the 'Computer Analysis with Stress-Strain Plot" Program

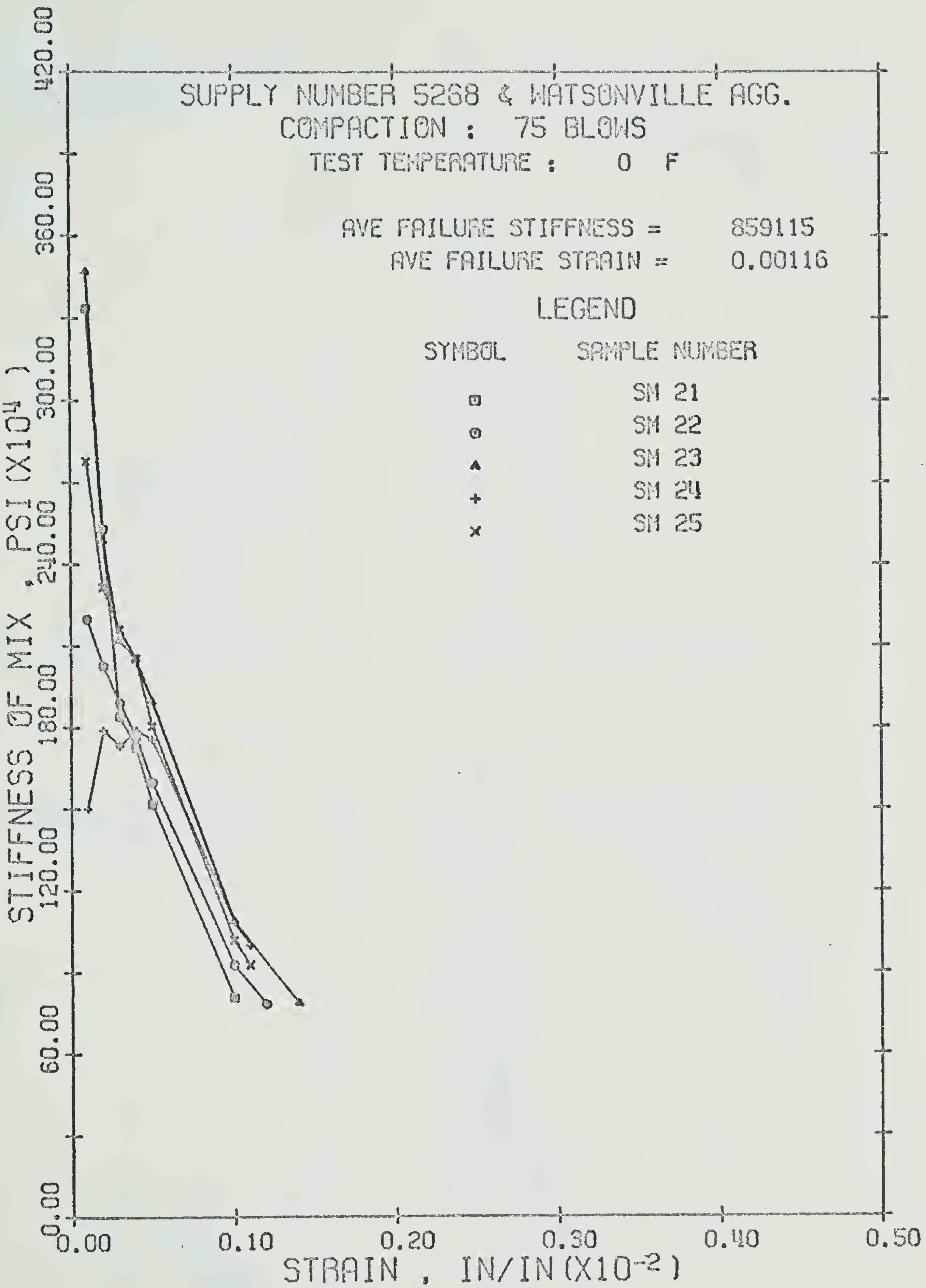


FIGURE 2.6 Sample Plot from the "Computer Analysis with Stiffness-Strain Plot" Program

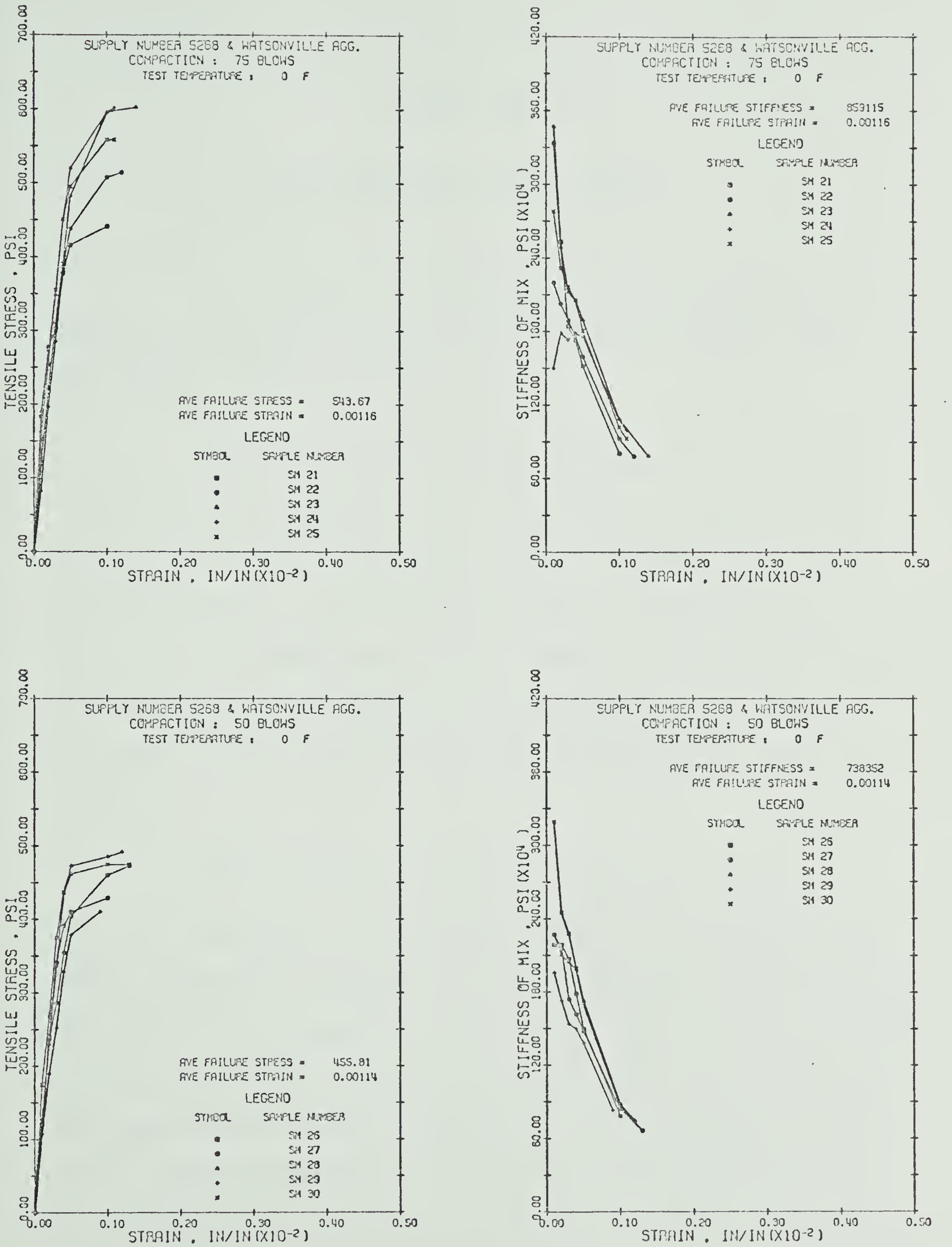


FIGURE 2.7 Sample Plot from the "Computer Analysis with Stress-Strain and Stiffness-Strain Plots" Program

CHAPTER III

APPLICATION OF TEST RESULTS

This chapter is structured as two separate examples of the application of test results obtained from the tensile splitting test.

The first part is the analysis of test results of the tensile splitting test conducted on asphaltic concrete cores from a four-lane divided freeway facility in central Alberta. Cores were obtained at construction as well as at the following service lives: 18 months, 32 months and 34 months. The cores were subjected to the tensile splitting test at test temperatures of 20°, 10°, 0° and -10°F.

The second part is the analysis of alternate laboratory specimen preparation methods to determine the impact compaction required to yield specimens equivalent to that obtained by kneading compaction. Comparisons were made on the basis of air voids and unit weight, as well as the low temperature tensile properties of the asphaltic concrete. Other information included in the second part of this chapter, is a summary of the preliminary investigation

into the effect of compaction upon the low temperature tensile properties of asphaltic concrete.

PART A: HIGHWAY 2-D-2/1 & 2/2 TEST PROJECT

During the summer of 1966 the Alberta Department of Highways in cooperation with the Alberta Research Council undertook an extensive highway testing program as part of the final asphaltic concrete paving of a four-lane divided freeway facility in central Alberta (Shields et al., 1969). In order to obtain additional information on the possible environmental conditions contributing to low temperature transverse cracking, and the influence of asphalt source, the Department of Highways decided to incorporate within one paving contract three different sources of 200-300 penetration grade asphalt cement. The three sources represented major suppliers of asphalt in the province, and will be referred to in the subsequent discussions as Asphalt Supply Numbers 1, 2 and 3.

Normal construction quality control procedures of the Department of Highways were maintained throughout the project. In addition, an extensive evaluation and testing program was implemented, which was primarily directed towards determining changes in the asphalt cement. As well as tests run upon the asphalt cements and the mixtures, field cores were obtained from each of the three test sections for further laboratory testing. The majority

of the laboratory tests conducted on the field cores were of a conventional nature, but as indicated by Shields et al (1969) certain of the tests were specialized and would be reported in due course.

The tensile splitting test was one of the special tests referred to specifically, and the subsequent discussion outlines the relationships between asphalt source, cracking frequency, and the low temperature tensile properties of the asphalt concrete cored pavement specimens. In addition to this correlation, Hahn (1967) established a similar correlation between asphalt source and the low temperature tensile properties of asphalt concrete laboratory specimens, prepared using Asphalt Supply Numbers 1, 2 and 3 and the design values for each mix. A report on this work is given by Anderson and Hahn (1968).

In addition to the field cores obtained at the time of construction, cores were also obtained from the three test sections at service lives of 18, 32 and 34 months. Of the specimens obtained, 214 were subjected to laboratory tests involving density determinations, followed by the tensile splitting test at temperatures of 20°, 10°, 0° and -10°F.

The computer analysis incorporated the application of each of the five programs mentioned in Chapter II. However, the two programs of greatest significance for this

study, were the "Detailed Computer Analysis" and the "Computer Analysis with Stress-Strain and Stiffness-Strain Plots". The output from the Detailed Computer Analysis for the 214 specimens total 298 pages, therefore reference will only be made to the statisitcal summaries included at the end of each series rather than to individual test results. A sample of the output from the "Detailed Computer Analysis" program is referred to in Appendix A, Section 8.2.2. The Calcomp plots of stress versus strain and stiffness versus strain for each of the test series represented by the 214 specimens are included in Appendix B.

ANALYSIS OF RESULTS FROM TENSILE SPLITTING TEST

Upon analysis, it was found that the results for the 18 month series exhibited higher failure stresses, lower failure strains and higher failure stiffnesses than would be expected by observing the established trends from the "At Construction" series to the 32 and 34 month series. In attempting to explain this apparent anomaly it was noted that the coring of all other specimens was completed when the air and pavement temperatures were above freezing. In the case of the 18 month cores the coring was conducted at air temperatures at or below -30°F. The overall effect produced by coring at such a low temperature is not fully understood, but the fact that parameters such as failure

stress, failure strain, and failure stiffness were significantly different, as compared to the cores at service lives both preceding and following the 18 month test series, has been considered as sufficient cause to warrant further investigation into the effects of coring at low temperatures. Because of the time element involved that type of reserach is beyond the scope of this thesis.

In the plotting of trends given in FIGURES 3.1, 3.2, and 3.3 points are plotted to represent the various parameters at construction as well as at the three service lives of 18 months, 32 months and 34 months. The discussion of trends will be limited to the change in parameters from the "At Construction" value to the centroid of the 32 and 34 month value. In addition, for the purpose of this study, the reporting and analysis of test results is confined to the specimens tested at $0^{o}F$. This test temperature was chosen, due to the fact that the previous investigation of the same materials by Hahn (1967), involved the tensile splitting test at only the one temperature of $0^{o}F$.

The following discussions compare the change in parameters with time for each of the three asphalt supplies. The discussion and explanation of results are made largely with reference to FIGURES 3.1, 3.2 and 3.3 augmented as required by information available from the computer output for the specimens or series of specimens tested.

CHANGE IN DENSITY WITH TIME

In addition to the plots of density versus age in FIGURES 3.1, 3.2 and 3.3 the information in TABLE I provides a means of comparing the effect of service life upon the unit weight and air voids as compared to the Marshall Mix Design values. (Note: The densities and air voids reported as design values are as reported by Hahn (1967). The densities and air voids for the two ages are based upon the volumetric computations completed in the "Detailed Computer Analysis" for the specimens subjected to the tensile splitting test. The "N" values given indicate the total number of specimens tested at that age).

The three asphalt cements considered had the following "as supplied" penetrations and viscosities (Hahn, 1967);

SUPPLIER	PENETRATION at 77°F	VISCOSITY at 140°F
1	265	237
2	215	610
3	217	544

Employing current terminology (McLeod, 1967) Asphalt Supply Number 1 is a "low viscosity" asphalt cement, Asphalt Supply Number 2 is a "high viscosity" asphalt cement, and Asphalt Supply Number 3 is

TABLE I

SUMMARY OF DENSITIES AND AIR VOIDS

HIGHWAY 2-D-2/1 & 2/2

SUPPLIER	CONDITION	UNIT WEIGHT (PCF)	AIR VOIDS (%)
1	Design	144.5	3.9
(N=20)	At Construction	138.6	8.1
(N=34)	32 & 34 Month Ave.	147.0	2.5
2	Design	144.6	4.2
(N=18)	At Construction	137.0	9.3
(N=31)	32 & 34 Month Ave.	142.0	6.0
3	Design	145.3	4.1
(N=21)	At Construction	134.0	12.1
(N=31)	32 & 34 Month Ave.	141.4	7.6

an "intermediate viscosity" asphalt cement. The increase in density with service life correlates well with the viscosities at 140°F. Asphalt Supply Number 1, the low viscosity asphalt cement, demonstrates both the greatest magnitude of change in density as well as the greatest percent change in density with service life. As can be seen from a comparison of FIGURES 3.1, 3.2 and 3.3, Asphalt Supply Number 1 also exhibits the highest crack frequencies. This observation of the rapid densification of a low viscosity asphalt pavement verifies the affirmation that "The use of softer grades of asphalt to minimize transverse cracking is questioned in view of observed rapid densification of the pavement surfaces in service" (Shields et al, 1969).

CHANGE IN FAILURE STRESS WITH TIME

Asphalt Supply Number 1 exhibits the greatest change in failure stress at the test temperature of 0°F. There is a 60 per cent increase in failure stress for the length of time considered for Asphalt Supply Number 1. The increase in failure stress over the same period for Asphalt Supply Number 2 is only 6 per cent; this is considered to be insignificant since the coefficient of variation for the average failure stress at each age generally ranged from 6 to 15 per cent. Asphalt Supply Number 3 exhibits an increase in failure stress of 30 per cent over the same service life.

In summary, for the data available within this study, the low viscosity asphalt cement mix exhibits the greatest increase in failure stress, the intermediate viscosity asphalt mixture experiences a lesser increase in failure stress, but for the high viscosity asphalt cement mix there is no appreciable change in failure stress for the time interval considered.

CHANGE IN FAILURE STRAIN WITH TIME

The important aspects of the failure strain appear to be its actual magnitude as well as its rate of change with time. The low viscosity asphalt cement, Asphalt Supply Number 1, has the lowest failure strain at the time of construction and at the 32 to 34 month age. The intermediate viscosity asphalt cement, Asphalt Supply Number 3, has the highest failure strain at the time of construction and at the 32 to 34 month age. It is interesting to note that the crack frequencies correlate with this parameter in that Asphalt Supply Number 1 exhibits 187 cracks per mile on the average, and Asphalt Supply Number 3 exhibits an average of 88 cracks per mile.

CHANGE IN STIFFNESS OF MIX AT FAILURE WITH TIME

It is to be expected that the trends in stiffness of mix will directly reflect the changes that have

already occurred in failure stress and failure strain. However, the stiffness of mix consideration does allow a single approach to the trends that occur jointly in the failure stress and failure strain.

The low viscosity asphalt mix, Asphalt Supply Number 1, exhibits a 185 per cent increase in stiffness over the time interval considered. Asphalt Supply Number 2 shows a 33 per cent increase in stiffness over the same period, while Asphalt Supply Number 3 demonstrates a 95 per cent increase in stiffness of mix at failure, from the time of construction to the 32 to 34 month test period.

CHANGE IN CRACK FREQUENCY WITH TIME

The crack frequencies indicated in FIGURES 3.1, 3.2 and 3.3 are the average number of cracks per mile based on the total number of miles reported (FIGURE 13, Shields et al, 1969).

The marked increase in cracking in all three asphalt supply sections over the winter of 1968-69 may be explained by the fact that the 1966-67 and 1967-68 winters were considered equivalent to the long-term average for central Alberta, but the winter of 1968-69 was considered to be one of the most severe in central and northern Alberta in the past 75 years.

SUMMARY OF RESULTS FOR HIGHWAY 2 TEST PROJECT

TABLE II provides a summary of tensile splitting test information for the Highway 2 Test Project. The design values of failure stress and failure strain were obtained by the tensile splitting test at 0°F on field cores at various service lives.

In conjunction with TABLES I and II, the analysis of the tensile splitting test data for the Highway 2 Test Project yields the following results:

1) The increase in cracking frequency was accompanied by a decrease in failure strain, and an increase in failure stress and failure stiffness.

2) The increase in density with service life was accompanied by a decrease in failure strain, and an increase in failure stress, failure stiffness, and cracking frequency.

3) In terms of a relative comparison, the pavement section with the highest crack frequency, also had the lowest failure strain and the highest failure stress and failure stiffness.

4) In terms of service life Asphalt Supply Number 1, the low viscosity asphalt cement mix, exhibited the greatest change in density, failure

TABLE II

SUMMARY OF TENSILE SPLITTING TEST INFORMATION

HIGHWAY 2-D-2/1 & 2/2 TEST TEMPERATURE 0°F

	SUPPLY NUMBER 1	SUPPLY NUMBER 2	SUPPLY NUMBER 3
DESIGN VALUES (Hahn, 1967)			
Failure Stress (psi)	490	480	490
Failure Strain (in/in)	.00074	.00151	.00165
AT CONSTRUCTION			
Failure Stress (psi)	302	289	194
Failure Strain (in/in)	.00082	.00105	.00138
Failure Stiffness (psi)	699,000	599,000	336,000
32 MONTHS SERVICE			
Failure Stress (psi)	460	305	270
Failure Strain (in/in)	.00056	.00102	.00083
Failure Stiffness (psi)	1,679,000	579,000	623,000
34 MONTHS SERVICE			
Failure Stress (psi)	505	310	263
Failure Strain (in/in)	.00047	.00061	.00082
Failure Stiffness (psi)	2,296,000	1,071,000	704,000
PAVEMENT PERFORMANCE (Number of Cracks/Mile)			
After 1st Winter	4	Nil	Nil
After 2nd Winter	87	Nil	4
After 3rd Winter	187	126	88

stress, failure strain, and failure stiffness, and the highest cracking frequency per mile.

PART B: ANALYSIS OF ALTERNATE LABORATORY SPECIMEN PREPARATION METHODS

During the spring of 1968, Anderson (1968) prepared 91 laboratory specimens at the Institute of Traffic and Transportation Engineering, University of California. He used one aggregate, that being the Watsonville aggregate, (State of California Grading 1/2" Max. Med.) and the following asphalt supplies and grades: Chevron 60/70, 85/100, and 120/150; Santa Maria 85/100; and Golden Bear 85/100. These specimens, prepared with strict control on gradation, density, and asphalt content, were compacted by the kneading compaction method, and then subjected to the tensile splitting test at temperatures of 40°, 30°, 20° and 0°F.

As a further example of the use of the computer analysis methods, the test results which were available were processed using the "Detailed Computer Analysis" and the "Computer Analysis with Stress-Strain and Stiffness-Strain Plots". The Calcomp plots of stress versus strain and stiffness versus strain for each of the test series are included in Appendix C.

COMPARISON OF KNEADING AND IMPACT COMPACTION

A correlation between kneading and impact compaction must be established if comparisons are to be made between the test results of the California specimens and those tested at The University of Alberta. In attempting to establish this correlation, laboratory specimens were prepared by means of the impact compaction apparatus (Soil test Model AP-195) using Watsonville aggregate and Santa Maria 85/100 asphalt cement. Five specimens, subsequently tested at $0^{o}F$, were prepared at each of 10, 50 and 75 blows at the required mixing and compacting temperatures as determined by the temperature-viscosity relationship for the Santa Maria asphalt cement.

The purpose of the laboratory tests was to determine the compactive effort required, using the impact apparatus, to achieve the same density as the kneading compaction method. It was found that the density and air voids at 75 blows agreed favourably with the density and air voids obtained with the kneading compaction as shown by the following data:

	KNEADING COMPACTION	IMPACT COMPACTION 75 Blows	50 Blows	10 Blows
Unit Weight (PCF)	153.56	153.34	152.11	143.18
Air Voids (%)	4.46	4.60	5.36	10.92

A second method of determining which impact compactive effort corresponded to the kneading compaction involved a plot of the failure stress versus the failure strain on a log plot, as given in FIGURE 3.4. It should be noted that the 91 points plotted and referred to as "California Asphalt-Kneading Compaction" comprise five distinctly different asphalt cements (including three different asphalt suppliers) and tensile splitting test temperatures of 40°, 30°, 20° and $0^{\circ}F$. The plot of all the points for this one aggregate and compactive method fall within a unique envelope as indicated by Anderson (1968).

The second degree equation of the best fit curve (APL Program Library Number 115, University of Alberta) of all the points for the California asphalts and kneading compaction is as follows:

$$Y = 4{,}858{,}000\ X^2 - 101{,}500\ X + 727\ ,$$

with a standard deviation of 57 psi, considering X as the independent variable, and Y as the dependent variable.

Where X = failure strain $\times 10^{-4}$ (in/in), and

Y = failure stress (psi) .

By substituting the average failure strain for each of the 10, 50 and 75 blow series into this equation, a deviation from the best fit curve may be determined. On this basis, the average failure stress for the 10 blow

series lies 5.5 standard deviations away from the best fit curve. Similarly, the 50 blow series is 2.9 standard deviations below the best fit curve, while the 75 blow series is 1.3 standard deviations below the best fit curve.

In order to complete the cross-referencing of asphalt supplies and aggregates between Alberta and California materials, three sets of specimens were prepared with Watsonville aggregate and Alberta Asphalt Supply Numbers 1, 2 and 3, as described in Chapter II. The specimens, prepared using 75 blow impact compaction, were subjected to the tensile splitting test at a temperature of $0^{\circ}F$.

The failure stress and failure strain values have been plotted on FIGURE 3.4. The failure stress of Asphalt Supply Number 1, the low viscosity asphalt cement, lies 2.1 standard deviations below the best fit curve. Similarily, Asphalt Supply Number 2, the high viscosity material, lies 0.6 standard deviations away from the best fit curve, while the intermediate viscosity asphalt cement, Asphalt Supply Number 3, is only 0.1 standard deviations from the best fit curve considered.

EFFECT OF COMPACTION ON THE LOW TEMPERATURE TENSILE PROPERTIES OF ASPHALTIC CONCRETE

The results of the previously mentioned specimens prepared at 10, 50 and 75 blow impact compaction have been summarized on a plot in FIGURE 3.5.

The trends of the low temperature tensile properties of the asphaltic concrete are as anticipated. However, in terms of magnitude of change, the 7 per cent decrease in density from 75 blows to 10 blows results in a 50 per cent loss in failure stress, a 36 per cent increase in failure strain, and a 64 per cent drop in stiffness of mix at failure when the specimens were subjected to the tensile splitting test at a temperature of $0^{\circ}F$.

Summary of Results for Alternate Laboratory Specimen Preparation Methods

The analysis of the alternate laboratory specimen preparation methods yields the following results:

1. The 75 blow impact compaction produced a density equivalent to that obtained by kneading compaction. However, further research should be undertaken to establish a more definite trend of the low temperature tensile properties to allow a comparison of the effect of the two laboratory specimen preparation methods.

2. For a given mix and given test conditions, a decrease in the density reduced the failure stress and failure stiffness, but increased the magnitude of the failure strain.

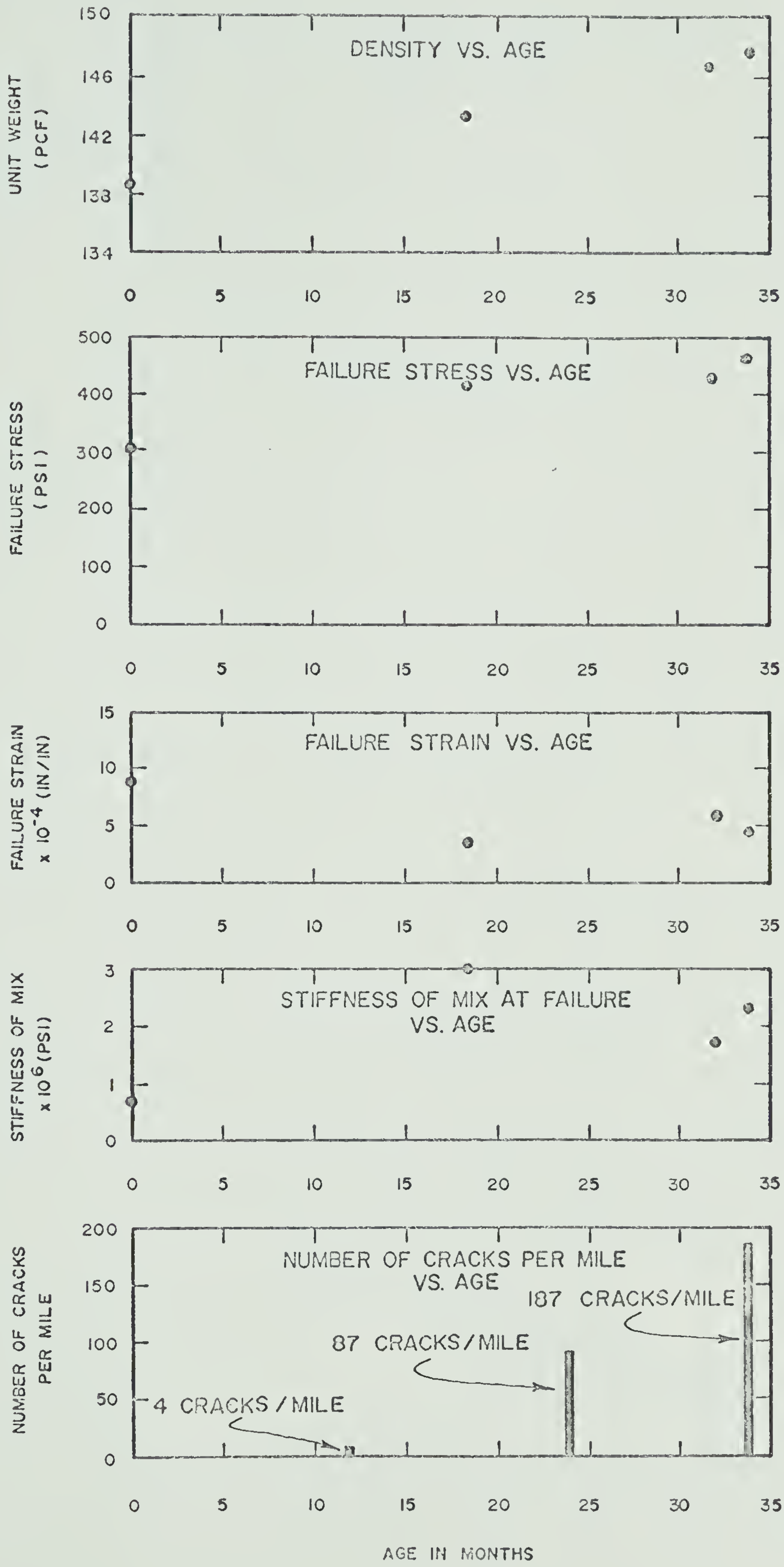


FIGURE 3.1 Change in Asphaltic Concrete Properties with Time, Asphalt Supply No. 1, Tensile Splitting Test Temperature 0°F.

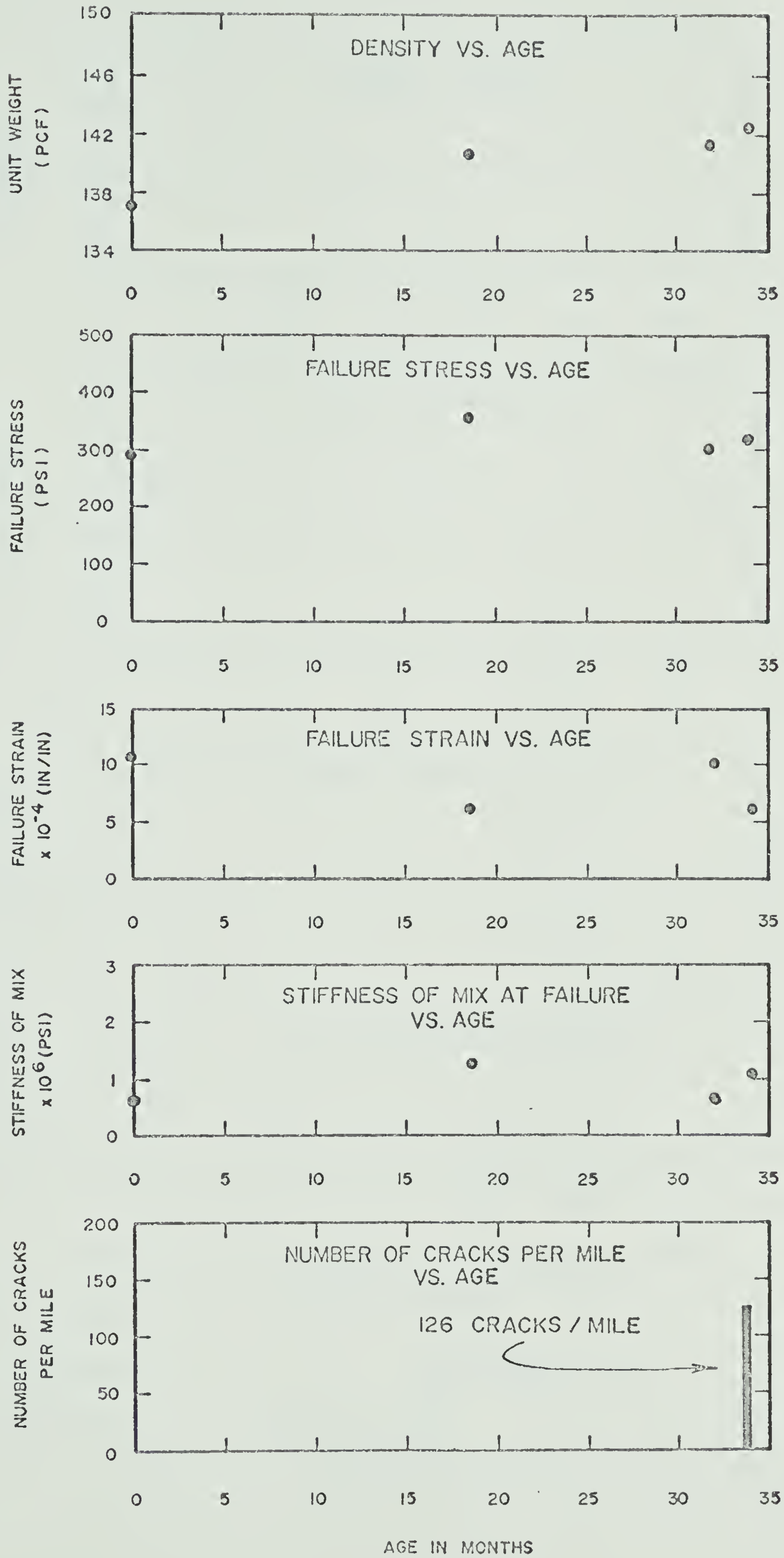


FIGURE 3.2 Change in Asphaltic Concrete Properties with Time, Asphalt Supply No. 2, Tensile Splitting Test Temperature 0°F.

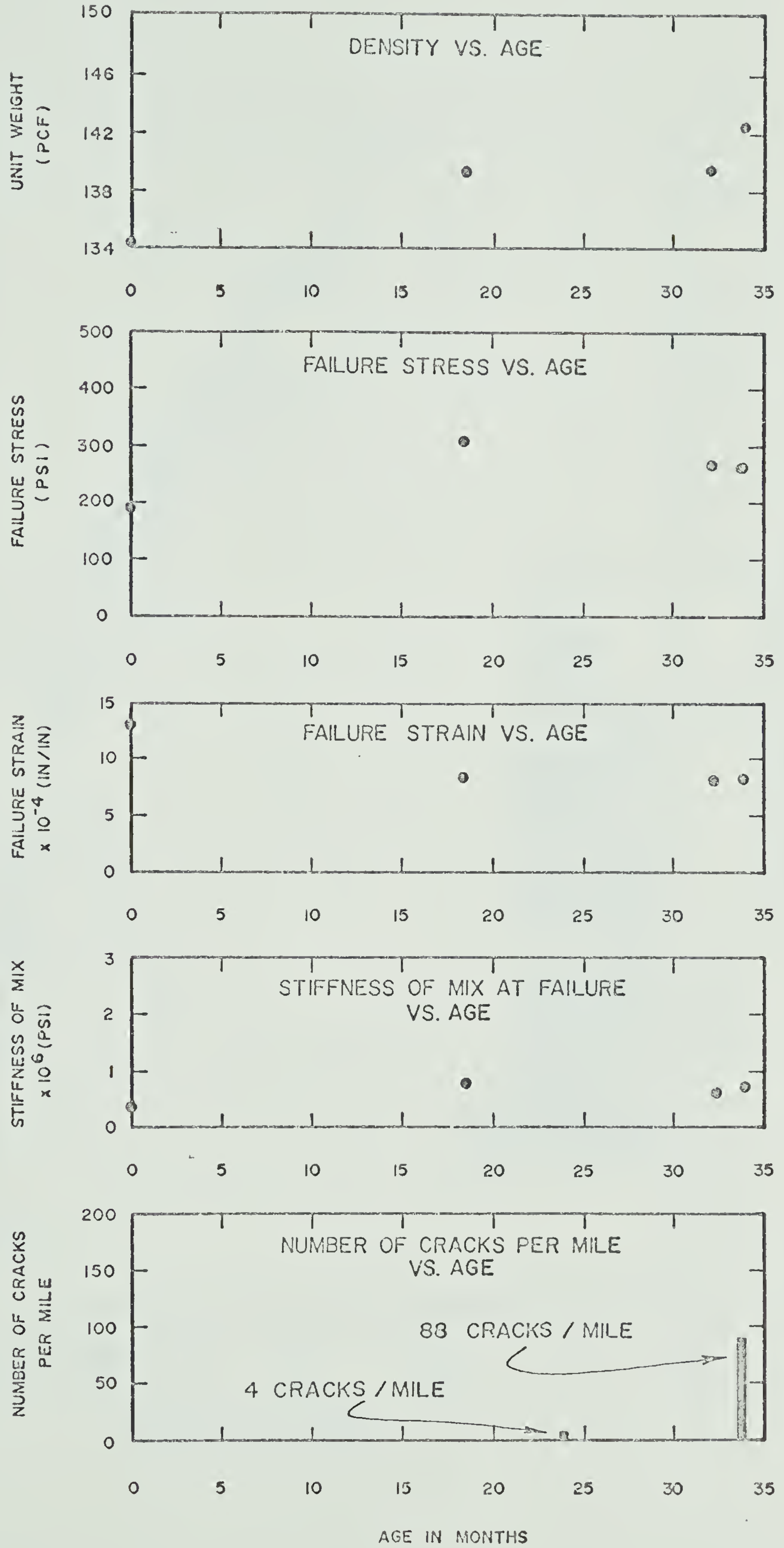


FIGURE 3.3 Change in Asphaltic Concrete Properties with Time, Asphalt Supply No. 3, Tensile Splitting Test Temperature 0°F.

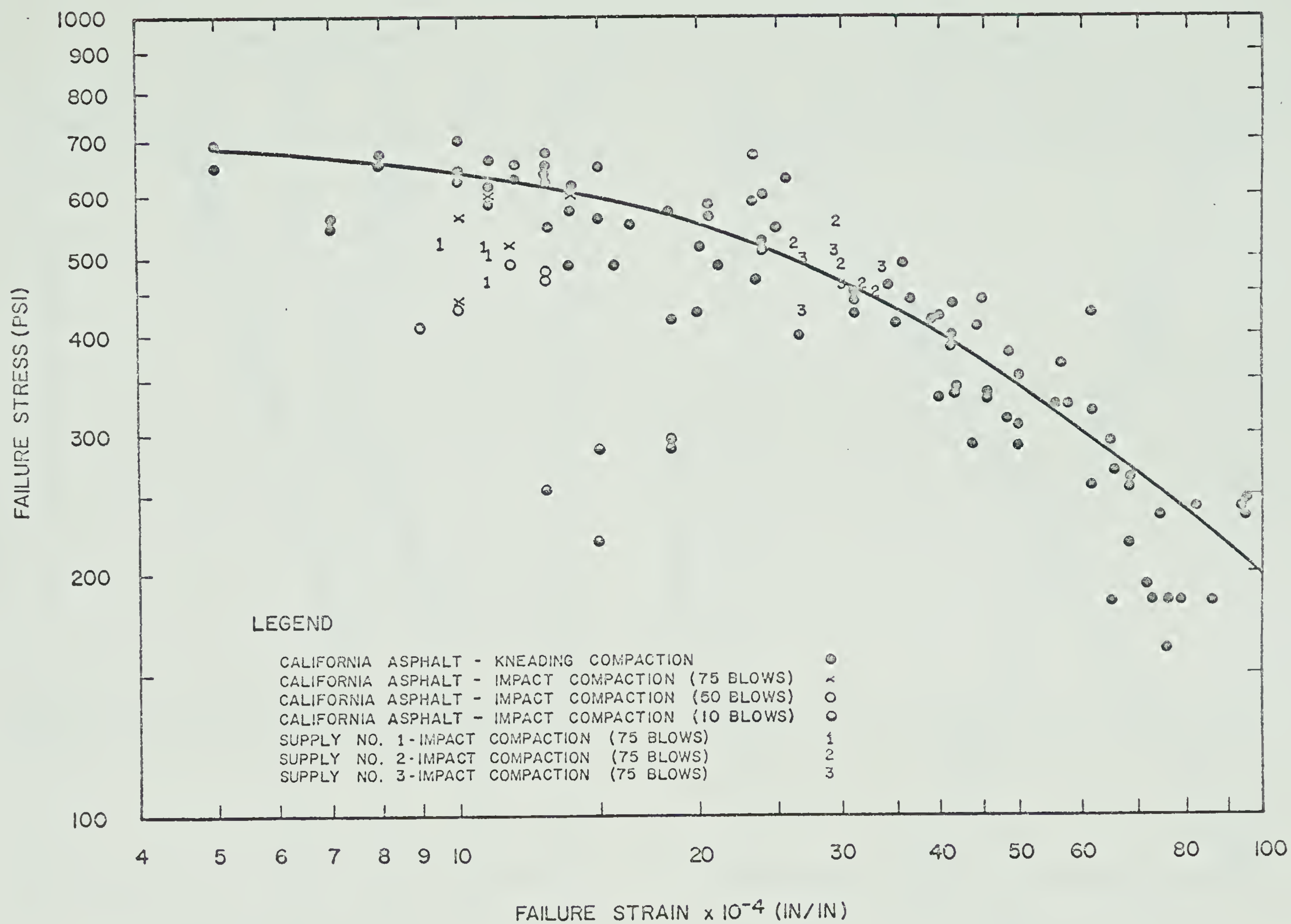


FIGURE 3.4 Plot of Failure Stress Versus Failure Strain

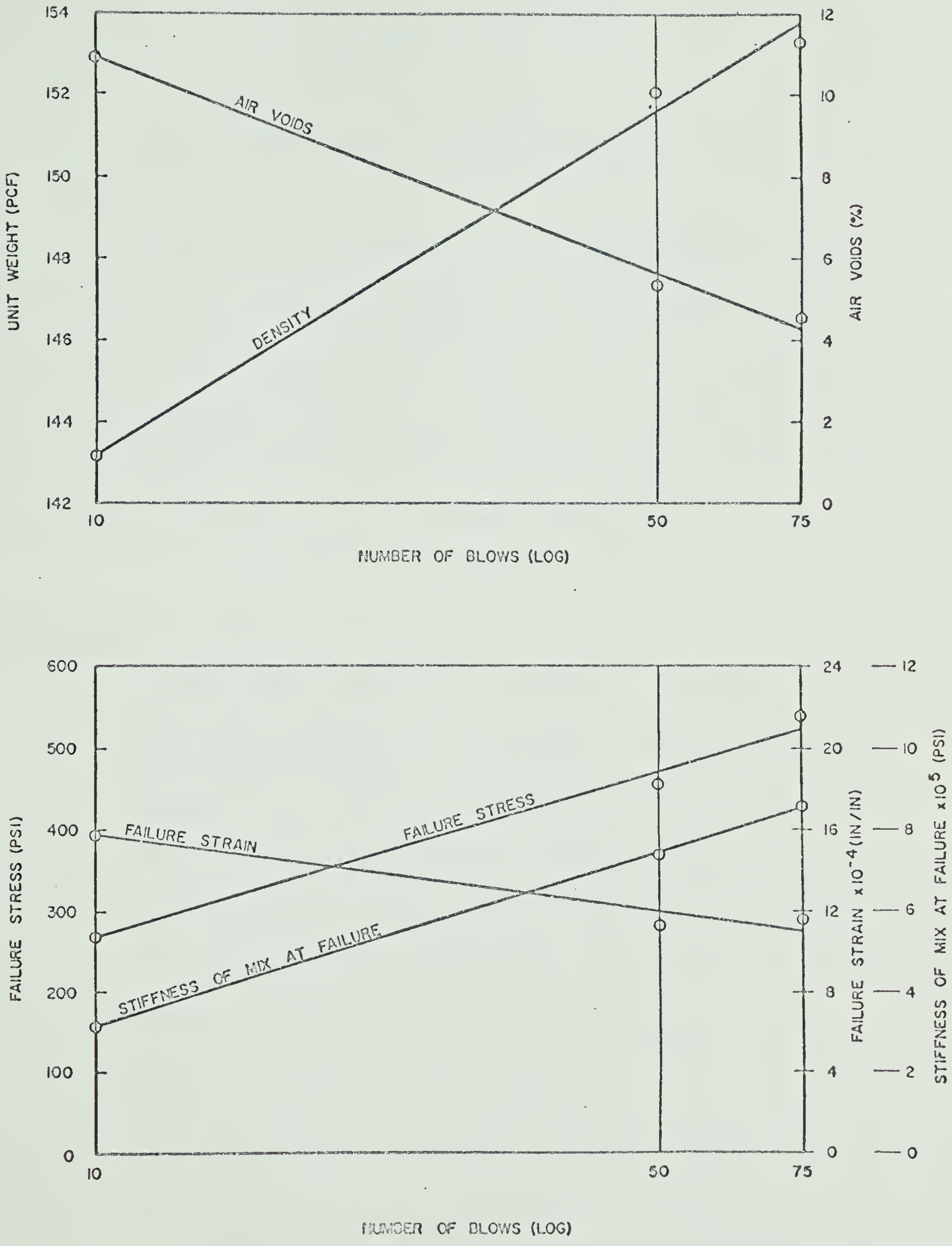


FIGURE 3.5 Effect of Compaction Upon Density, Air Voids, and Low Temperature Tensile Properties. Watsonville Aggregate and Santa Maria 85/100 Asphalt Cement, Tensile Splitting Test Temperature 0°F.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

The general purpose of this investigation was to develop and demonstrate the use of a computerized method of analysis for the tensile splitting test used to determine the low temperature tensile properties of asphaltic concrete. The extent of the achievement of this purpose will be indicated in this portion of the thesis.

CONCLUSIONS

1. The computer analysis programs developed within this thesis permit a thorough study of the low temperature tensile properties of asphaltic concrete. The programs are written with a built-in flexibility so that they may be used by others with a minimum of difficulty, and with the freedom of revising the test conditions as the research or analysis may require.

2. Conclusions from the Highway 2 test project:

   (a) An increase in cracking frequency is accompanied by a decrease in failure strain, and an increase in failure stress and failure stiffness.

(b) An increase in density with service life is accompanied by a decrease in failure strain, and an increase in failure stress, failure stiffness, and cracking frequency.

(c) In terms of relative comparisons the pavement section with the highest crack frequency, also has the lowest failure strain and the highest failure stress and failure stiffness.

(d) In terms of service life, the low viscosity asphalt cement exhibits the greatest change in density, failure stress, failure strain, and failure stiffness, and the highest cracking frequency per mile.

3. Conclusions from the analysis of alternate laboratory specimen preparation methods:

(a) The 75 blow impact compaction yields a density equivalent to that obtained by kneading compaction.

(b) For a given mix, and given test conditions a decrease in the density reduces the failure stress and failure stiffness, but increases the magnitude of the failure strain.

RECOMMENDATIONS

1. In the design and evaluation of asphalt pavements subjected to low temperatures, the tensile splitting test and analysis methods should be adopted to determine the low temperature tensile characteristics of the asphaltic concrete.

2. In future research programs, involving the testing of field cores over a particular service life, the following steps should be considered:

   (a) establish coring locations at the time of construction with the use of random numbers,

   (b) complete all future coring under environmental conditions as close to the original as is feasible,

   (c) the location of the cores to be obtained for various service lives should be in the same general area as the original randomly selected locations, to allow for a better measure of trends due to time alone, and

   (d) keep a separate series for the upper and lower course materials. The difference is minimal at the time of construction, but is of considerable importance as the surface course is subjected to the weathering and aging elements.

RECOMMENDATIONS FOR FURTHER STUDY

1. The tensile splitting test should be altered to determine the effect of different loading rates, and to establish values for Poisson's ratio for different temperatures and different loading rates.

2. Investigate the relationship between the low temperature tensile properties, as measured by the tensile splitting test, and the recovered properties of asphalt cement for various service lives.

3. Determine the value of the additional parameters computed within the "Detailed Computer Analysis" program (i.e., Stiffness of Bitumen, Bitumen Strain, Toughness, and Work Input) as an indicator of cracking susceptibility for asphaltic concrete.

4. Investigate the possible effects of temperature at coring on the low temperature tensile properties of asphalt concrete cylinders.

LIST OF REFERENCES

LIST OF REFERENCES

Anderson, K.O., and Hahn, W.P., "Design and Evaluation of Asphalt Concrete with Respect to Thermal Cracking". Proceedings, Association of Asphalt Paving Technologists, Volume 37, 1968.

Anderson, K.O., "An Investigation of the Low-Temperature Tensile Properties of Asphalt Concrete with Some California Materials". Unpublished Report of Limited Circulation, Prepared for Prof. C.L. Monismith, I.T.T.E., June 27, 1968.

Breen, J.J. and Stephens, J.E., "Split Cylinder Test Applied to Bituminous Mixtures at Low Temperatures". Journal of Materials, Volume 1, Number 1. March, 1966.

Christison, J.T., "The Tensile Splitting Test Applied to Thermal Cracking of Asphalt Pavements". Unpublished Master's Thesis, University of Alberta, Faculty of Graduate Studies, 1966.

Gillespie, K.R., "Applications of the Tensile Splitting Test to Asphalt Concrete Mixtures at Low Temperatures". Unpublished Master's Thesis, University of Alberta, Faculty of Graduate Studies, 1966.

Hahn, W.P., "Evaluation of Asphalt Concrete Mixed with Respect to Thermal Cracking". Unpublished Master's Thesis, University of Alberta, Faculty of Graduate Studies, 1967.

Heukolom, W., "Observations on the Rheology and Fracture of Bitumens and Asphalt Mixes". Proceedings, Association of Asphalt Paving Technologists, 1966.

McLeod, N.W., "Critical Appraisal of the Proposal to Grade Paving Asphalts by Viscosity at 140^{o}F, "American Society for Testing and Materials, STP 424, 1967.

Shields, B.P., Anderson, K.O., and Dacyszyn, J.M., "An Investigation of Low Temperature Transverse Cracking of Flexible Pavements", Paper Presented to the Canadian Good Roads Association Conference, October, 1969.

APPENDIX A

METHOD OF TEST AND ANALYSIS FOR THE LOW TEMPERATURE TENSILE PROPERTIES OF ASPHALT CONCRETE CYLINDERS USING THE TENSILE SPLITTING TEST

METHOD OF TEST AND ANALYSIS FOR THE LOW TEMPERATURE TENSILE PROPERTIES OF ASPHALT CONCRETE CYLINDERS USING THE TENSILE SPLITTING TEST

1. Scope

1.1 This method covers the procedure developed for determining the low temperature tensile properties of asphalt concrete cylinders using the tensile splitting test. The test can be conducted on asphalt concrete laboratory specimens and cored pavement specimens (Note 1).

NOTE 1 - For method of making laboratory specimens see The Standard Method of Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus (ASTM Designation: D 1559-65). Alternate methods for preparation of laboratory specimens may be used.

2. Summary of Method

2.1 The tensile splitting test method consists of loading an asphalt concrete cylinder via loading strips across a diameter, in a compression testing frame and within a controlled temperature chamber maintained at a constant low temperature. Output signals from a load cell and two series connected linear variable differential transformers

(attached to opposite ends of the specimen) are monitored on a two channel recorder. From the load trace and the deformation trace a limited analysis of the test can result in failure stress, failure strain, and a manually plotted stress-strain diagram. The limited analysis is covered in sections up to and including Sections 7.1.5.

2.2 More detailed analyses involving the use of an IBM 360-67 Computer and a Model 770/663 Calcomp Plotter at the University of Alberta Computing Center are also used and are described in detail in Sections 7.2. to 8.5.1. The computer program summarizes the physical properties of the specimen as well as various computed parameters at several points throughout the duration of the test. At the completion of a particular test series, a statistical summary giving the mean, standard deviation, and coefficient of variation of the parameters considered is provided for a more meaningful analysis. In addition, with the use of the Calcomp Plotter automatically plotted stress-strain and stiffness-strain plots are developed for the specimens within a test series.

3. <u>Significance</u>

3.1 This method determines the tensile stress-strain and stiffness-strain characteristics of asphalt concrete at low temperatures and is primarily intended to assist in the design and evaluation of asphalt concrete with respect to thermal cracking.

4. Apparatus

4.1 Controlled Temperature Chamber - The controlled temperature chamber shall be capable of maintaining test specimens at a constant temperature $\pm 2^{\circ}$ within the range of $+40^{\circ}$ to $-10^{\circ}F$ during the course of a test. A temperature monitoring device shall have its sensor embedded in a specimen of similar size and composition to the specimen which is to be tested and shall be capable of measuring temperature to $\pm 1^{\circ}F$.

4.2 Loading apparatus shall consist of the following:

4.2.1. Compression Testing Frame[1] - The Compression frame shall have a minimum capacity of 5 tons and shall be capable of providing the rate of loading prescribed in Section 6.4.1.

4.2.2. Supplementary Bearing Bar or Plate - The supplementary bearing bar or plate shall conform to the specifications for this item in the Standard Method of Test for Splitting Tensile Strength of Molded Concrete Cylinders (ASTM Designation: C 496-66), except that the width of the bearing bar or plate shall be not less than 1.3 inches.

4.2.3. Bearing Strips - The bearing strips shall conform to the specifications for this item in Method C 496-66, except that nominal 3/16 inch plywood, approximately 1/4 inches wide shall be used.

---

1. A suitable device (Wykeham Farrance Mod. 57, 5 ton compression tester) may be obtained from Wykeham Farrance Engingeering, Ltd., 127 Edinburgh Avenue, Slough, Bucks, U.K.

4.3 Load Measurement Apparatus shall consist of the following:

4.3.1. Load Cell[2] - The load cell shall have a minimum capacity of 5 tons and shall be capable of measuring compressive loading to ±1 per cent of true at the rate of loading prescribed in Section 6.4.1.

4.4 Gauge Points, and Marking and Mounting Apparatus shall consist of the following:

4.4.1. Gauge Points - The gauge points shall be 3/8 x 3/8 x 3/16 inches (± 0.001 inches from mean in any dimension) brass plates.

4.4.2. Gauge Point Jig - The gauge point jig shall provide slots for marking the specimen and holes for mounting the Gauge Points (Fig. A1 of Anderson & Hahn, 1968).

4.5 Deformation Measurement Apparatus shall consist of the following:

4.5.1. Displacement Gauges[3] - The displacement gauges shall be two series connected linear variable differential transformers of matched sensitivity (within 5%) and be capable of measuring displacements to within ±0.00005 inches, and shall have a stroke of not less than ±0.010 inches.

---

2. A suitable device (Kwoya Musen Load Cell Mod. LC-5,5 ton) may be obtained from Kwoya Musen Kenkyujo Co., Ltd., Tokyo, Japan.
3. Suitable devices Sanborn Linear Variable Differential Transformers Mod. 595 DT 025) may be obtained from the Sanborn Co. 175 Wyman Street, Waltham 54, Massachusetts, U.S.A.

4.5.2 Displacement Gauge Core and Coil Assemblies - The two displacement gauge core and coil assemblies which hold the Displacement Gauges shall be made of brass (Fig. A2 of Anderson & Hahn, 1968).

4.5.3 Displacement Gauge Calibration Jig - The displacement gauge calibration jig shall be made of brass and aluminum (Fig. A3 of Anderson & Hahn, 1968). The dial gauge which comprises a portion of the displacement gauge calibration jig shall be a 0.00001 inch dial gauge.

4.6 Recorder[4] - The Recorder shall be of a type having two channels capable of providing a load trace on one channel, from the output signal generated by the Load Cell, and a deformation trace on the second channel, from the output signal generated by the Displacement Gauges.

5. Test Specimens

5.1 Asphalt Concrete Laboratory Specimens - If Marshall specimens are to be tested they shall conform to the specifications set forth in ASTM Method D 1559-65.

5.2 Asphalt Concrete Cored Pavement Specimens - If cored pavement specimens are to be tested they shall be trimmed to a cylindrical shape (within ±0.01 inches of the mean length and diameter) having a diameter of 4 inches, ± 0.10 inches and a length of less than 4 inches.

4. A suitable device (Sanborn Recorder Model 311) may be obtained from the Sanborn Company.

6. Procedure

6.1 Calibration consists of the following:

6.1.1. Load Cell - The Load Cell shall be calibrated at room temperature (if temperature compensating) or at the test temperature (if non-temperature compensating), on a Compression Tester whose load accuracy has been verified to ± 1 per cent in accordance with the Standard Methods of Verification of Testing Machines, ASTM Designation: E4-64. It is recommended that the load be calibrated on Channel B of the Recorder.

6.1.2. Dial Gauge - The dial gauge shall be calibrated while on the Displacement Gauge Calibration Jig described in Section 4.5.3, using machinist's gauge blocks.

6.1.3. Displacement Gagues - The two most closely matched Displacement Gauges shall be chosen on the basis of separate calibration of each available Displacement Gauge at room temperature on the Displacement Gauge Calibration Jig. Then the two Displacement Gauges shall be series connected and calibrated on the Displacement Gauge Calibration Jig (using a 1.000 inch gauge length at null) at the test temperature. It is recommended that the deformation be calibrated on Channel A of the Recorder.

6.2 Preparation of Specimen for Testing is as follows:

6.2.1. Measurement - Determine the length and diameter of the test specimen to the nearest 0.01 inch by averaging four readings at each dimension.

6.2.2. Marking - Mark dimetral loading points on each end of the specimen in the same axial plane using the Gauge Point Jig described in Section 4.4.2.

6.2.3. Gauge Point Attachment - Coat one side of each of two gauge points (described in Section 4.4.1.) with warm asphalt cement. Insert the two coated Gauge Points through the holes in the aligned Gauge Point Jig and press firmly onto the specimen. Store the specimen horizontally in a cold atmosphere for approximately 15 minutes to firmly affix the gauge points to the specimen. Remove the specimen from the cold atmosphere, invert the specimen (and prop in a manner that will not disturb the previously attached Gauge Points) and attach the other two Gauge Points in a similar manner.

6.2.4. Cooling - Immediately place the specimen into the Controlled Temperature Chamber.

6.3. Preparation for Loading of the Specimen is as follows:

6.3.1. Specimen Inspection - After the specimen to be tested has reached equilibrium temperature, inspect it for Gauge Point Slippage. If any slippage is evident remove the Gauge Points and repeat steps 6.2.3 and 6.2.4.

6.3.2. Positioning - Place the Load Cell on the loading ram platen of the Compression Testing Frame. Position the specimen so that the marked loading points are in a vertical plane passing through the center of thrust and so that the longitudinal axes of the plywood Bearing Strips are in this vertical plane. Raise the loading ram of the Compression Testing Frame just enough to secure the specimen for Displacement Gauge attachment.

6.3.3. Displacement Gauge Attachment - Tie both of the Displacement Gauge Core and Coil Assemblies to some point on the Compression Testing Frame to obviate damage after specimen failure. Simultaneously place the rear Displacement Gauge Core and Coil Assembly onto the Gauge Points and then secure the assemblies by tightening the allen screws. Repeat the foregoing attachment procedure for the front Displacement Gauge Core and Coil Assembly.

6.4. Loading and Recording procedure is as follows:

6.4.1. Loading Rate - Set the Compression Testing Frame to a nominal loading rate of 0.06 in/min. The actual loading rate may vary from the nominal loading rate by ± 10 per cent but must be reproducible within ± 1 per cent.

6.4.2. Loading - Engage the Compression Testing Frame and return to the recording area (Note: that loading will not begin until the power supply switch for the servo motor is closed. This switch should be located in the recording area, adjacent to the recorder).

6.4.3. Recording - Balance the resistance and capacitance of the Displacement Gauge Core and Coil Assemblies using the procedure indicated in the recorder manual. Engage the chart movement switch to establish a chart movement rate of 1 millimeter per second simultaneously with the closing of the power supply switch for the servo motor. Set the attenuation for each of channels A and B at the most sensitive calibrated scales that will be used. Align the recording pens for each of channels A and B along a line 5 millimeters in from the right hand markings on the strip chart. As the recorded load and deformation increase, the attenuation should be adjusted so that all recording takes place within the central 40 millimeters of the 50 millimeter tape width. All attenuation changes shall be indicated on the strip chart to facilitate establishment of proper scales. All other pertinent data such as date of test, test temperature, rate of loading, and specimen identification number shall be recorded on the strip chart at this time.

6.4.4. Termination of Test - Upon failure of the specimen disengage the chart movement switch, turn the attenuator for channel A to the off position, and disengage the power supply switch for the servo motor. Mark the failure point on the load trace on channel B (at the point where the slope first reaches zero). Project the corresponding point onto channel A to establish the failure strain. Disengage the Compression Testing Frame and examine the fractured specimen. If the fracture surface passes under a Gauge Point the test shall be rejected.

7. Calculations

7.1 Limited Analysis - The limited analysis may be conducted with simple calculations not requiring the use of a computer. The results obtainable with this method include failure stress, failure strain, and the coordinates of the stress-strain diagram.

7.1.1 Tensile Stress - The tensile stress at any point to failure shall be calculated as follows:

$$T = \frac{2P}{\pi t d}$$

where:

T = tensile stress, in pounds per square inch

P = applied load as indicated on channel B, in pounds

t = specimen thickness in inches and

d = specimen diameter, in inches.

7.1.2. Strain - The strain, at any point to failure is equal to the deformation, in inches, indicated on channel A of the Recorder (see Note 2).

NOTE 2 - Due to the biaxial state of stress existing within the cylindrical specimen, the displacement measured between the gauge points is a result of both compressive stresses in the vertical direction and tensile stresses in the horizontal direction. The term strain is used without differentiation as to its cause. If tensile strain is desired, as for calculation of a stiffness modulus, use of equations applying the Generalized Hooke's Law is necessary.

7.1.3. Failure Strain - The failure strain shall be considered as the strain corresponding to the point on channel A of the strip chart located by the projection of the point where the slope of the load trace on channel B first reaches zero.

7.1.4. Tensile Strength - The tensile strength shall be considered as the tensile stress calculated using the load corresponding to the point of failure (see 7.1.3.).

7.1.5. Report - The report for the Limited Analysis shall include the following:

(1) Identification number, aggregate identification, asphalt cement penetration or viscosity, and asphalt cement supply,

(2) Test temperature,

(3) Rate of loading,

(4) Specimen diameter, and thickness,

(5) The load and deformation strip chart,

(6) The failure strain,

(7) The tensile strength, and

(8) Any abnormalities in the type of fracture.

7.2. Computer Analyses

7.2.1. The computer analyses consists of five separate programs indicated as follows:

1) Basic computer analysis (section 7.3.)
2) Detailed computer analysis (section 7.4.)
3) Computer analysis with stress-strain plot (section 7.5.)
4) Computer analysis with stiffness-strain plot (section 7.6.)
5) Computer analysis with stress-strain and stiffness-strain plots(section 7.7.)

The programs indicated are progressively more complex in function and in the required establishment of the data decks. The relationship of one program to another, with respect to data cards, is best understood by making reference to the flow chart, Figure A1. The remaining topics covered in Section 7.2. indicate the procedure to be followed for obtaining information common to all computer programs.

7.2.2. Determine the number of sets of specimens to be processed during this run.

7.2.3. Establish a descriptive title (80 columns or less) that is to appear at the top of each page to identify each particular set. Generally it would include details pertaining to asphalt cement supply, grade, aggregate source, and the

FLOW CHART FOR ARRANGING DATA FOR ALL COMPUTER PROGRAMS

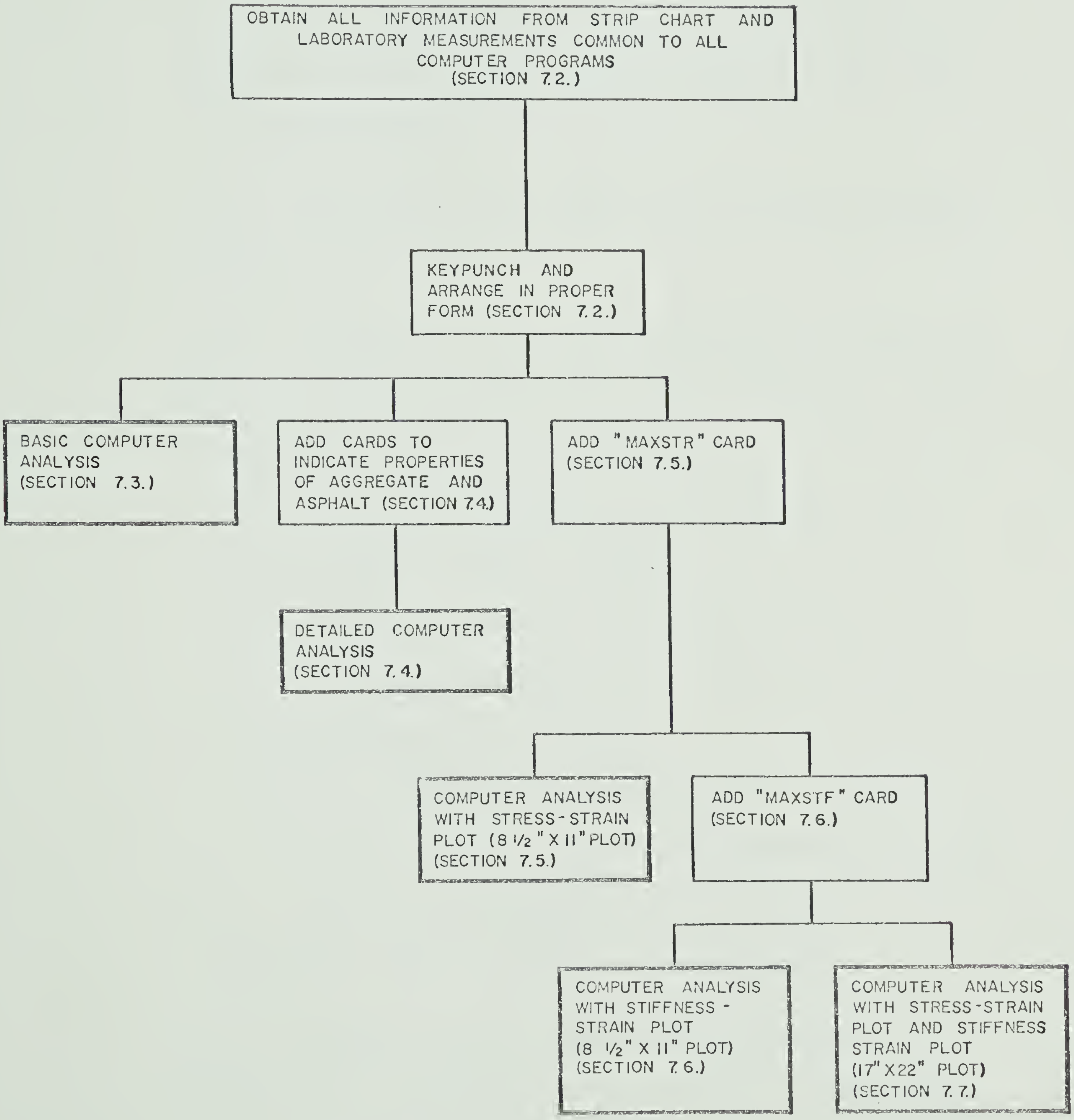


FIGURE A1: Flow Chart For Arranging Data For All Computer Programs

highway or test section description. It is not necessary to include specimen numbers, test temperature, loading rate, or date of test for all of this is included in a different format within the remainder of the computer analysis.

7.2.4. Note the test temperature in degrees Fahrenheit, the rate of loading in inches per minute, and the test date for each of the sets to be processed.

7.2.5. Determine the number of specimens tested within each series.

7.2.6. Summarize previously obtained information as it applies to the individual specimens tested. This will include the following:

(1) specimen identification number,

(2) weight in air, in grams,

(3) weight in water, in grams,

(4) diameter, in inches,

(5) thickness, in inches,

(6) the number of load and strain points picked off the load and deformation strip chart (see Section 7.2.7.), and

(7) the time to failure, in seconds.

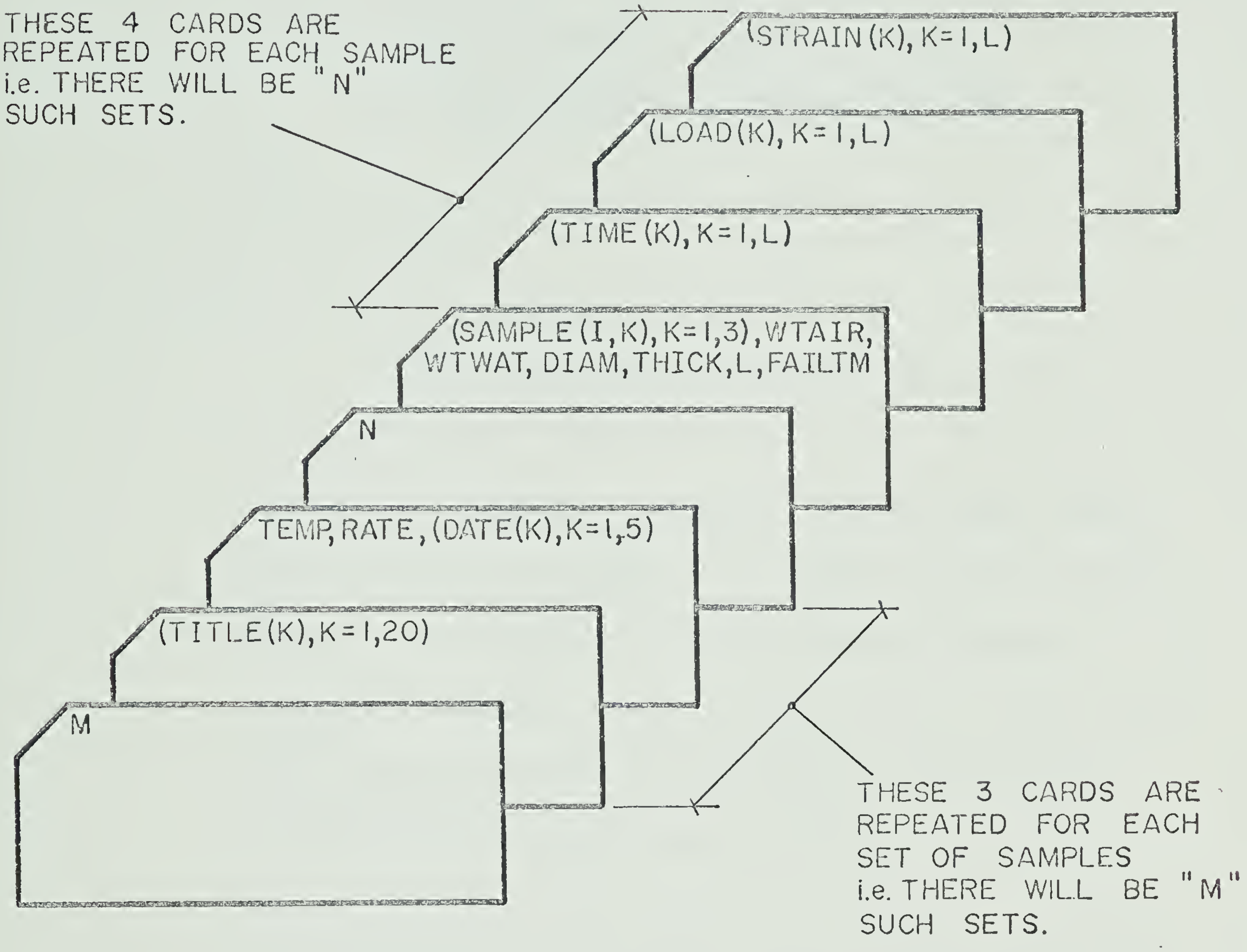
7.2.7. Several time, load, and deformation values are picked off the load and deformation strip chart, to provide the information required

to allow the computer analysis of various parameters throughout the loading of the specimen, up to the failure point. During the initial loading period, it should be realized that a certain amount of time and energy are required to compress the plywood loading strips, and that the load transferred to the specimen during this period would be of a very small order. This fact makes it necessary to establish the zero time by some criteria that would be indicative of the time at which the plywood strips are completely compressed, from this point forward the load is being carried entirely by the specimen. This zero time point, necessary for calculating the work input (Section 7.4.), is taken arbitrarily as the point at which the load trace shows a marked increase in slope after having held relatively constant with a load in the order of 300 to 600 pounds (this will vary with the type of plywood). To establish a sufficient number of points throughout the testing of the specimen, the time in seconds, load in pounds, and deformation in ten-thousandths of an inch should be recorded at the following deformation values up to the failure point (See Section 7.1.3.) (for simplicity all values of deformation are expressed as the number of ten-thousandths of an inch:

1, 2, 3, 4, 5, 10, 15, 20, 30, 40, etc. until failure).

7.2.8. All of the information summarized as outlined in Sections 7.2.2. - 7.2.7. shall be key-punched in the proper fields as indicated in the program listings. Since the same data cards will eventually be used in conjunction with the plotting programs, special care shall be exercised in establishing the title card. In the plotting programs the 80 column title is split into two 40 column titles and placed one above the other on the Calcomp Plotter output, therefore, the spacing of the title on the data card shall be properly spaced within columns 1 to 40, and columns 41 to 80, to develop a neatly spaced title on the computer plotted graphs.

7.2.9. Upon completion of all key-punching the data cards shall be arranged in the following order:



7.3. Basic Computer Analysis

7.3.1. The required job control cards, the "Basic Computer Analysis" program (in precompiled object deck form), and the data deck (as arranged in Section 7.2.9.) shall be arranged as follows:

```
// jobname  JOB  (user chg no,2,2),'BASIC COMPUTER
                                    ANALYSIS'
// stepname           EXEC          FORTHLG
```

```
// LKED. SYSIN            DD  *

        BASIC COMPUTER ANALYSIS PROGRAM
       (IN PRECOMPILED OBJECT DECK FORM)
/*
// GO. SYSIN              DD  *

       DATA DECK (SEE SECTION 7.2.9.)
/*
```

7.3.2. The computer listing of the "Basic Computer Analysis" program is referred to in Section 8.1.1. The output from the "Basic Computer Analysis" program shall consist of one sheet for each of the specimens tested, plus two sheets providing the statistical summaries for this particular set. Section 8.1.2 refers to an output typical of that which shall be provided for each of the specimens tested within this test series. When the last specimen within a series has been completed, statistical summaries shall be provided. The first statistical summary (Section 8.1.3.) is based upon initial conditions within the tensile splitting test. This point within each test corresponds to the maximum secant modulus of the stress-strain diagram (i.e. the maximum stiffness of mix for each particular specimen within this test series). The second statistical summary (Section 8.1.4.) is based

upon failure conditions within the tensile splitting test. The failure conditions within each specimen tested shall be considered as the point at which the failure strain (Section 7.1.3.) has been attained.

7.4 Detailed Computer Analysis

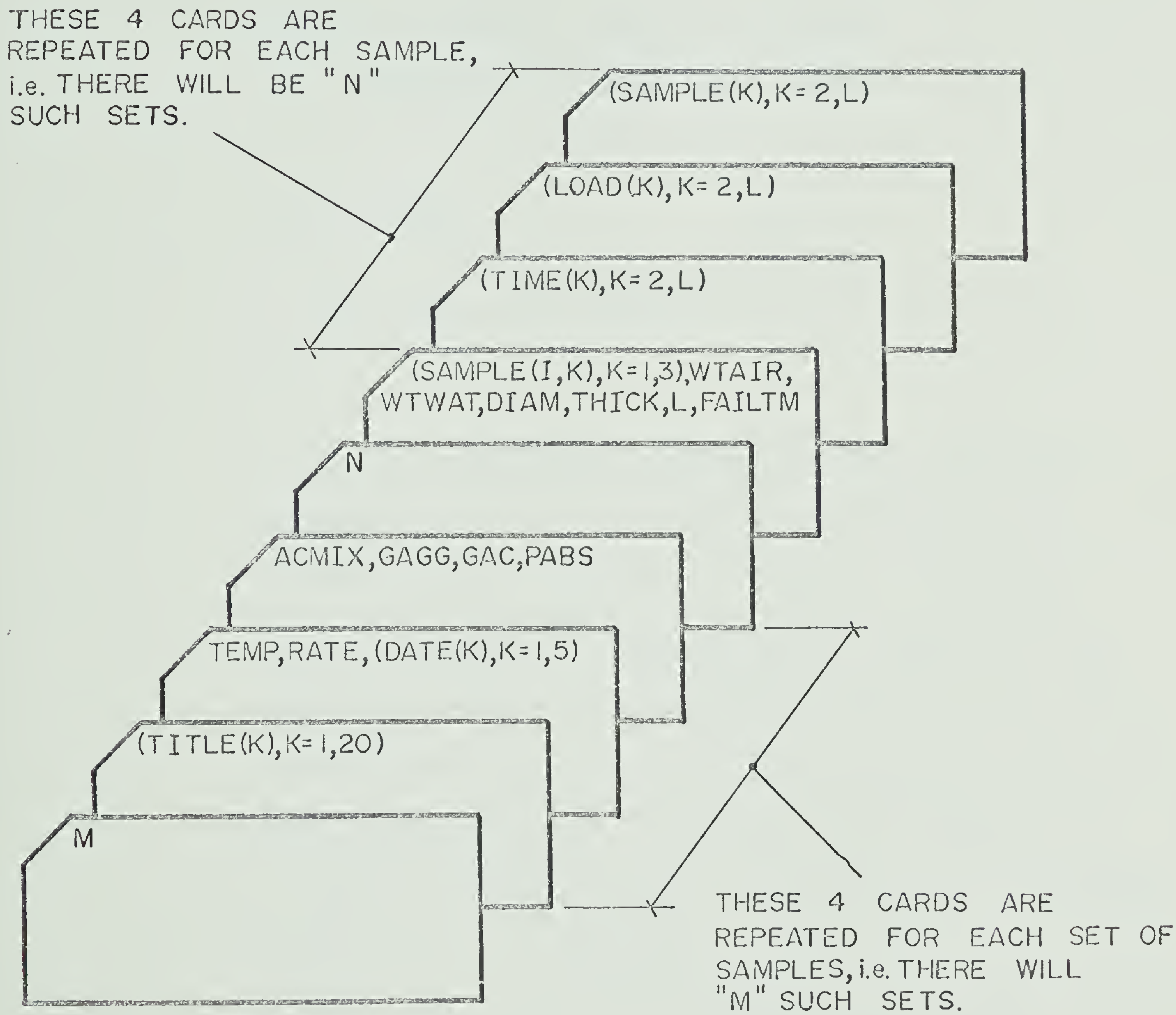
7.4.1. The data deck for the Detailed Computer Analysis shall consist of the data deck provided in Section 7.2.9. plus one additional card for each test series within this run. The one addit-ional card for each test series shall provide the following additional information:

1) asphalt content of the mix being tested, in pounds of asphalt cement per 100 pounds of dry aggregate,
2) bulk specific gravity of the aggregate,
3) bulk specific gravity of the asphalt cement, and,
4) per cent absorption of the aggregate, in pounds of asphalt cement absorbed per 100 pounds of dry aggregate.

7.4.2. The information summarized in Section 7.4.1. shall be key-punched in the proper fields as indicated in the program listing.

7.4.3. The data card for each test series as described in Sections 7.4.1. and 7.4.2. shall be added to the data deck described in Section 7.2.9.

immediately following the "Temperature, Rate, and Date" card, and just prior to the "N" card. The data deck for the "Detailed Computer Analysis" shall be arranged in the following order:



7.4.4. The required job control cards, the "Detailed Computer Analysis" program (in pre-compiled object deck form), and the data deck (as arranged in Section 7.4.3.) shall be arranged

as follows:

```
// jobname  JOB  (user chg no, 2,2), 'DETAILED
                              COMPUTER ANALYSIS'
// stepname         EXEC          FORTHLG
// LKED. SYSIN                DD   *
DETAILED COMPUTER ANALYSIS PROGRAM
 (IN PRECOMPILED OBJECT DECK FORM)
/ *
// GO. SYSIN                  DD  *
   DATA DECK (SEE SECTION 7.4.3.)
/ *
```

7.4.5. The computer listing for the "Detailed Computer Analysis" program is referred to in Section 8.2.1. The output from the "Detailed Computer Analysis" program shall consist of one sheet for each of the specimens tested, plus two sheets providing the statistical summaries for this particular set. Section 8.2.2. refers to an output typical of that which shall be provided for each of the specimens tested within this test series. Section 8.2.3. refers to an output typical of that which shall be given for the statistical summary based upon initial conditions, while Section 8.2.4. similarily refers to the statistical summary based upon final conditions. The terms initial and final as used within this

program and this section shall be as defined in Section 7.3.2.

7.5. Computer Analysis with Stress-Strain Plot

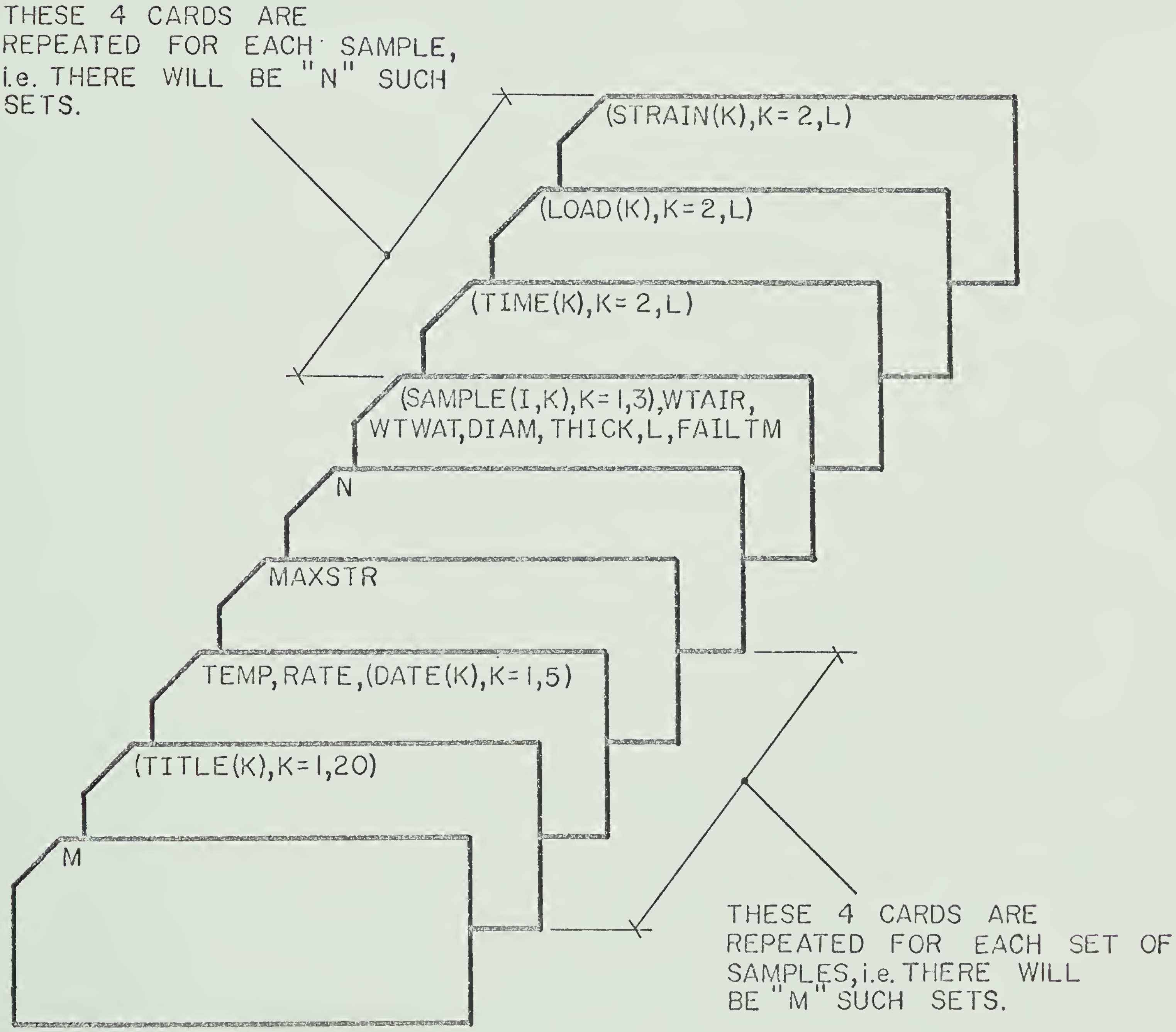
7.5.1. Upon inspection of test results within each test series, the maximum failure strain, in ten thousandths of an inch/inch, attained by any specimen within a series shall be noted. This maximum failure strain value shall be used to establish the appropriate scale for the tensile strain, in inches/inch, as measured along the X-axis of the stress-strain plot. The maximum failure strain may be any value, but since the X-axis on the stress-strain plot is five inches in length the most convenient scales will be obtained if the number chosen is a multiple of five. The following values for the variable "MAXSTR" produce convenient scales:

MAXSTR	SCALE
10	1" = 2 ten thousandths of an in/in
25	1" = 5 ten thousandths of an in/in
50	1" = 10 ten thousandths of an in/in
100	1" = 20 ten thousandths of an in/in

7.5.2. The value corresponding to the maximum failure strain for each test series as described in Section 7.5.1. shall be key-punched in the proper field as indicated in the program listing.

7.5.3. The data card for each test series as

described in Section 7.5.1. and 7.5.2. shall be added to the data deck described in Section 7.2.9. immediately following the "temperature, rate, and date" card, and just prior to the "N" card. The data deck for the "Computer Analysis with Stress-Strain Plot" shall be arranged in the following order:



7.5.4. The plotting operation requested by this type of computer program is an off-line operation that necessitates the intermediate storage of data to be plotted on a seven track magnetic tape. In order for this program to run successfully, one must have access to a seven track tape mounted by the computer operator prior to the execution of the program. This can be accomplished by the following:

1) add, CLASS = B to the first job control card, (See Section 7.5.5.).
2) add two job control cards to indicate the plot parameters and the code number of the seven track plotting tape. These two cards shall be placed after the /* card following the object deck, and prior to the //GO. SYSIN DD * card immediately preceding the data deck (See Section 7.5.5.).
3) complete tape mounting slip and plot request slip as required by the Computing Center (See Section 7.5.6. and 7.5.7.). These two slips must accompany the program when being submitted for processing.

7.5.5. The required job control cards, the "Computer Analysis with Stress-Strain Plot" program (in precompiled object deck form), and the data deck (as arranged in Section 7.5.3.).

shall be arranged as follows:

```
/ / jobname   JOB   (user chg no, 2,2), 'COMP ANALYSIS-STRESS
                                          STRAIN PLOT', CLASS = B
/ / stepname            EXEC                        FORTHLG
/ / LKED. SYSIN                       DD  *

        COMPUTER ANALYSIS WITH STRESS-STRAIN PLOT
            (IN PRECOMPILED OBJECT DECK FORM)
/ *
/ / GO.PLOTTAPE  DD   UNIT = SYS7T, DISP = (NEW KEEP),
                                   DSNAME = PLOTTAPE,
/ /  VOLUME = SER = tape number, LABEL = (1,SL), DCB = (DEN = 1)
/ / GO. SYSIN                         DD  *

             DATA DECK (SEE SECTION 7.5.3.)
/  *
```

7.5.6. The tape mounting slip shall be as required by the University of Alberta Computing Centre.

7.5.7. The plotter request slip shall be as required by the University of Alberta Computing Centre.

7.6 Computer Analysis with Stiffness-Strain Plot

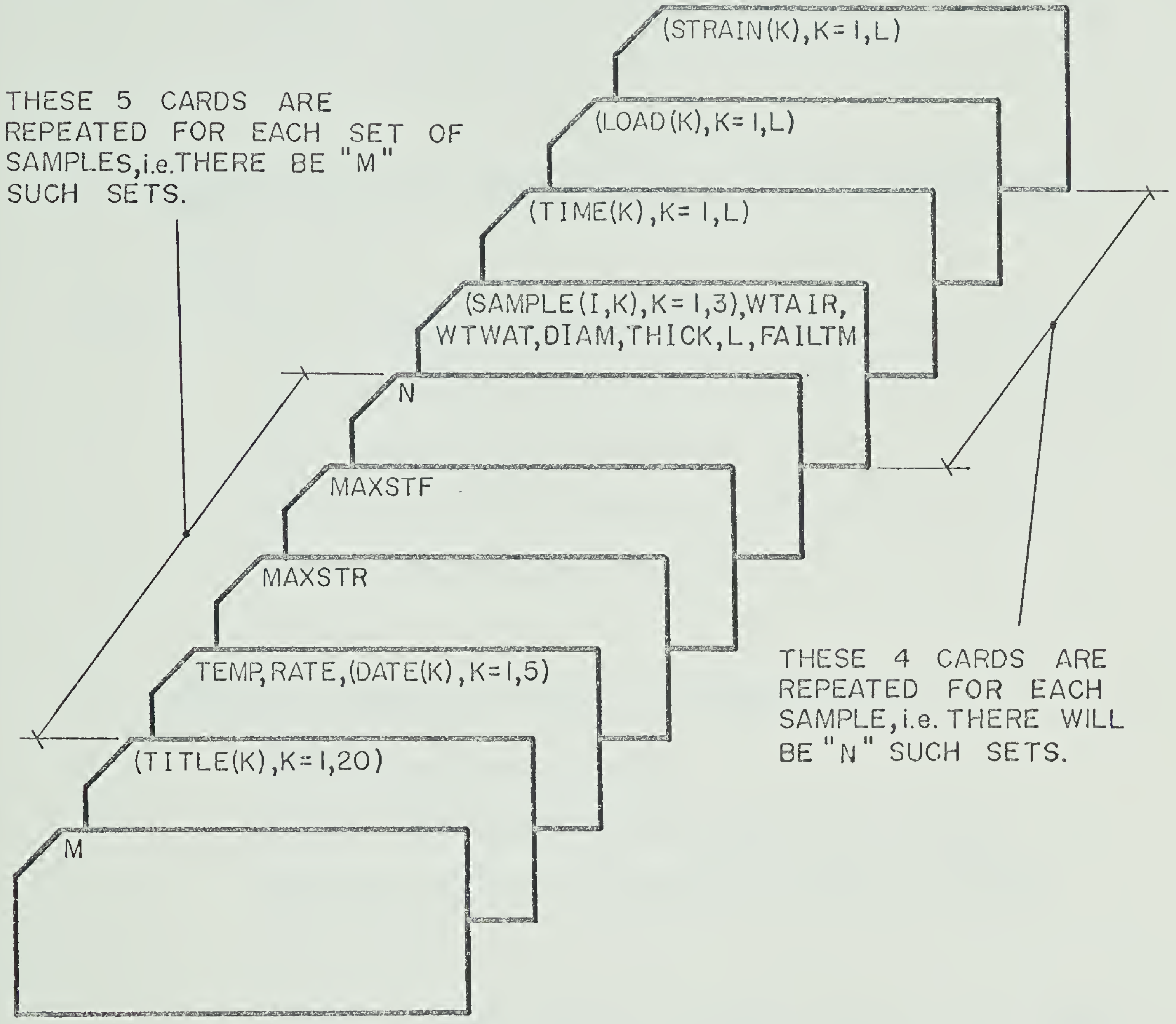
7.6.1 Upon inspection of test results within each test series, the maximum failure strain, in ten thousandths of an inch/inch, attained by any specimen within a series shall be noted. This maximum failure strain value shall be used to establish the value of the variable "MAXSTR", as indicated in Section 7.5.1. The appropriate value for the variable "MAXSTR" shall be key-punched as indicated in Section 7.5.2., and added to the data deck as indicated in Section 7.5.3.

7.6.2 Upon inspection of test results within each test series, the maximum stiffness of mix, in pounds per square inch, attained by any specimen within a series shall be noted. This maximum stiffness of mix value shall be used to establish the appropriate scale for the stiffness of mix, in pounds/square inch, as measured along the Y-axis of the stiffness-strain plot. The maximum stiffness of mix may be any value, but since the Y-axis on the stiffness-strain plot is seven inches in length the most convenient scales will be obtained if the number chosen is divisible by seven. The following values for the variable "MAXSTF" produce convenient scales:

MAXSTF	SCALE
700000	1" = 100,000 PSI
1400000	1" = 200,000 PSI
2100000	1" = 300,000 PSI
2800000	1" = 400,000 PSI
3500000	1" = 500,000 PSI
Etc.	
7000000	1" = 1,000,000 PSI

7.6.3 The value corresponding to the maximum stiffness of mix for each test series as described in Section 7.6.2. shall be keypunched in the proper field as indicated in the program listing.

7.6.4 The data card for each test series as described in Section 7.6.2. and Section 7.6.3. shall be added to the data deck described in Section 7.5.3. immediately following the "maximum strain" card, and just prior to the "N" card. The data deck for the "Computer Analysis with Stiffness-Strain Plot" shall be arranged in the following order:



7.6.5. The off-line plotting operation for the "Computer Analysis with Stiffness-Strain Plot" program shall be the same as that described in Section 7.5.4. Section 7.5.5. also applies to this program except that the precompiled object deck shall be that for the "Computer Analysis with Stiffness-Strain Plot". In addition, the

tape mounting slip and plotter request slip shall be the same as that described in Sections 7.5.6. and 7.5.7.

7.7 Computer Analysis With Stress-Strain and Stiffness-Strain Plots

7.7.1. All aspects of this program shall be the same as that described in Section 7.6. with the exception that the precompiled object deck shall be that for the "Computer Analysis with Stress-Strain and Stiffness-Strain Plots".

8. Computer Program Listings and Sample Output

8.1. Basic Computer Analysis

8.1.1. The computer listing of the "Basic Computer Analysis" program is given on pages A33 to A37.

8.1.2. A page typical of that giving the output for each specimen within a test series for the "Basic Computer Analysis" program is given on page A38.

8.1.3. A page typical of that giving the statistical summary based upon initial conditions (as described in Section 7.3.2.) for the specimens within a test series analyzed with the "Basic Computer Analysis" program is given on page A39.

8.1.4. A page typical of that giving the statistical summary based upon failure conditions (as described in Section 7.3.2.) for the specimens within a test series analyzed with the "Basic Computer Analysis" program is given on page A40.

8.2. Detailed Computer Analysis

8.2.1. The computer listing of the "Detailed Computer Analysis" program is given on pages A41 to A48.

8.2.2. A page typical of that giving the output for each specimen within a test series for the "Detailed Computer Analysis" program is given on page A49.

8.2.3. A page typical of that giving the statistical summary based upon initial conditions (as described in Section 7.3.2.) for the specimens within a test series analyzed with the "Detailed Computer Analysis" program is given on page A50.

8.2.4. A page typical of that giving the statistical summary based upon failure conditions (as described to Section 7.3.2.) for the specimens within a test series analyzed with the "Detailed Computer Analysis" program is given on page A51.

8.3 Computer Analysis With Stress-Strain Plot

8.3.1. The computer listing of the "Computer Analysis with Stress-Strain Plot" program is given on pages A52 to A59.

8.4 Computer Analysis with Stiffness-Strain Plot

8.4.1. The computer listing of the "Computer Analysis with Stiffness-Strain Plot" program is given on pages A60 to A67.

8.5 Computer Analysis with Stress-Strain and Stiffness-Strain Plots

8.5.1. The computer listing of the "Computer Analysis with Stress-Strain and Stiffness-Strain Plots" program is given on pages A68 to A77.

```
ISN 0002          DIMENSION TITLE(20),DATE(5),TIME(20),LOAD(20),STRAIN(22),STRESS(22
                 1),FLSTRS(20),FLSTRN(20),FLTIME(20),SAMPLE(20,3),STIFF(20),FLSTFF(2
                 20),ORSTRS(20),ORSTRN(20),ORSTFF(20),ORTIME(20),UNITWT(20)
ISN 0003          INTEGER TIME,SAMPLE,FAILTM,TEMP
ISN 0004          REAL LOAD
            C
            C
            C           M = THE NUMBER OF SETS OF SAMPLES TO BE PROCESSED DURING
            C               THIS RUN .
            C
            C
ISN 0005          READ(5,10)M
ISN 0006       10 FORMAT(I5)
ISN 0007          DO 300 II=1,M
            C
            C
            C       TITLE = A DESCRIPTION (80 COLUMNS OR LESS) TO APPEAR AT THE
            C               TOP OF EACH PAGE TO IDENTIFY EACH PARTICULAR SET .
            C
            C
ISN 0008          READ(5,20)(TITLE(K),K=1,20)
ISN 0009       20 FORMAT(20A4)
            C
            C
            C        TEMP = THE TEST TEMPERATURE , IN DEGREES FAHRENHEIT , AT
            C               WHICH THIS SET WAS RUN .
            C
            C        RATE = THE RATE OF LOAD APPLICATION IN INCHES PER MINUTE .
            C
            C        DATE = THE DATE AT WHICH THE SAMPLES WITHIN THIS SET
            C               WERE TESTED .
            C
            C
ISN 0010          READ(5,30)TEMP,RATE,(DATE(K),K=1,5)
ISN 0011       30 FORMAT(7X,I3,F10.3,5A4)
            C
            C
            C           N = THE NUMBER OF SAMPLES WITHIN THIS SET .
            C
            C
ISN 0012          READ(5,40)N
ISN 0013       40 FORMAT(I5)
ISN 0014          DO 200 I=1,N
            C
            C
            C      SAMPLE = THE IDENTIFICATION NUMBER OF THE SAMPLE .
            C
            C       WTAIR = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN AIR .
            C
            C       WTWAT = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN WATER .
            C
            C        DIAM = THE AVERAGE DIAMETER OF THE SAMPLE , IN INCHES .
            C
            C       THICK = THE AVERAGE THICKNESS OF THE SAMPLE , IN INCHES .
            C
            C           L = THE NUMBER OF LOAD AND STRAIN POINTS PICKED OFF THE
            C               LOAD AND DEFORMATION STRIP CHART .
```

```
                C
                C        FAILTM = THE TIME TO FAILURE , IN SECONDS .
                C
                C
ISN 0015              READ(5,50)(SAMPLE(I,K),K=1,3),WTAIR,WTWAT,DIAM,THICK,L,FAILTM
ISN 0016           50 FORMAT(3A4,F8.3,3F10.3,2I10)
                C
                C
                C          SPGR = BULK SPECIFIC GRAVITY OF THE COMPACTED MIXTURE .
                C
                C
ISN 0017              SPGR=WTAIR/(WTAIR-WTWAT)
                C
                C
                C        UNITWT = UNIT WEIGHT OF THE COMPACTED MIXTURE ,
                C                 IN POUNDS PER CUBIC FOOT .
                C
                C
ISN 0018              UNITWT(I)=SPGR*62.4
ISN 0019              LN=N+1
ISN 0020              NN=N+2
ISN 0021              WRITE(6,60)(TITLE(K),K=1,20),I,NN,(SAMPLE(I,K),K=1,3),SPGR,UNITWT(
                     1I),DIAM,THICK
ISN 0022           60 FORMAT(1H1//////20X,20A4//91X,      5HPAGE ,I2,4H OF ,I2///44X,17H
                     1SAMPLE NUMBER :  ,3A4//32X,     49HBULK SPECIFIC GRAVITY OF THE COM
                     2PACTED MIXTURE = ,      F5.3//38X,14HUNIT WEIGHT = ,F5.1,22H POUNDS
                     2 PER CUBIC FOOT ,           //45X,11HDIAMETER = ,    F5.3,7H INCHES/
                     3/44X,12HTHICKNESS = ,      F5.3,7H INCHES//)
ISN 0023              WRITE(6,61) RATE,FAILTM,TEMP,(DATE(K),K=1,5)
ISN 0024           61 FORMAT(25X,15HDETAILS OF TEST//26X,18HRATE OF LOADING = ,F5.3,16H
                     1INCHES / MINUTE,4X,19HTIME TO FRACTURE = ,I3,8H SECONDS//26X,19HTE
                     2ST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,9HDATE :    ,5A4///)
ISN 0025              WRITE(6,62)
ISN 0026           62 FORMAT(60X,9HSTIFFNESS/30X,6HSTRESS,9X,6HSTRAIN,11X,6HOF MIX,10X,
                     14HTIME/31X,5H(PSI),9X,7H(IN/IN),10X,5H(PSI),9X,9H(SECONDS)////)
ISN 0027              DENOM=3.14159*DIAM*THICK
                C
                C
                C          TIME = THE TIME , IN SECONDS , FROM ZERO TIME TO EACH OF THE
                C                 POINTS ON THE LOAD AND DEFORMATION STRIP CHART .
                C
                C
ISN 0028              READ(5,70)(TIME(K),K=1,L)
ISN 0029           70 FORMAT(5X,15I5)
                C
                C
                C          LOAD = THE LOAD , IN POUNDS , AT EACH OF THE POINTS ON THE
                C                 LOAD TRACE .
                C
                C
ISN 0030              READ(5,80)(LOAD(K),K=1,L)
ISN 0031           80 FORMAT(5X,15F5.0)
                C
                C
                C        STRAIN = THE STRAIN , IN TEN THOUSANDTHS OF AN INCH / INCH ,
                C                 FOR EACH OF THE POINTS ON THE DEFORMATION TRACE .
                C
```

```
               C
ISN 0032             READ(5,90)(STRAIN(K),K=1,L)
ISN 0033          90 FORMAT(5X,15F5.0)
ISN 0034             DO 100 J=1,L
ISN 0035             STRESS(J)=2.*LOAD(J)/DENOM
ISN 0036             STRAIN(J)=STRAIN(J)*0.0001
               C
               C
               C        CONSIDERING AVERAGE TENSILE STRESS OVER A ONE INCH GAUGE LENGTH
               C        AND ASSUMING A POISSONS RATIO OF 0.33 .
               C
               C
ISN 0037             STIFF(J)=0.912*STRESS(J)/(STRAIN(J)*.5)
ISN 0038             ISTIFF=STIFF(J)
ISN 0039             WRITE(6,95)STRESS(J),STRAIN(J),ISTIFF,TIME(J)
ISN 0040          95 FORMAT(26X,F10.2,6X,F10.6,8X,I8,9X,I5/)
ISN 0041         100 CONTINUE
               C
               C
               C        SUBROUTINE 'MAX' IS CALLED TO DETERMINE THE MAXIMUM SECANT
               C        MODULUS ( THAT IS THE MAXIMUM STIFFNESS OF MIX FOR EACH
               C        STRESS-STRAIN DIAGRAM ) .
               C
               C
ISN 0042             CALL MAX(L,STIFF,NNN)
ISN 0043             ORSTRS(I)=STRESS(NNN)
ISN 0044             ORSTRN(I)=STRAIN(NNN)
ISN 0045             ORSTFF(I)=STIFF(NNN)
ISN 0046             ORTIME(I)=TIME(NNN)
ISN 0047             FLSTRS(I)=STRESS(L)
ISN 0048             FLSTRN(I)=STRAIN(L)
ISN 0049             FLSTFF(I)=STIFF(L)
ISN 0050             FLTIME(I)=TIME(L)
ISN 0051         200 CONTINUE
               C
               C
               C        SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
               C        DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
               C        BASED UPON INITIAL CONDITIONS ( THAT IS THE MAXIMUM SECANT
               C        MODULUS OF EACH STRESS-STRAIN DIAGRAM ) .
               C
               C
ISN 0052             CALL STATS(N,ORSTRS,XBAR5,SIGMA5,VAR5)
ISN 0053             CALL STATS(N,ORSTRN,XBAR6,SIGMA6,VAR6)
ISN 0054             CALL STATS(N,ORSTFF,XBAR7,SIGMA7,VAR7)
ISN 0055             CALL STATS(N,ORTIME,XBAR8,SIGMA8,VAR8)
ISN 0056             CALL STATS(N,UNITWT,XBAR9,SIGMA9,VAR9)
ISN 0057             IXBAR7=XBAR7
ISN 0058             ISGMA7=SIGMA7
ISN 0059             WRITE(6,210)(TITLE(K),K=1,20),LN,NN,N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0060         210 FORMAT(1H1//////20X,20A4//91X,      5HPAGE ,I2,4H OF ,I2///29X,
                    159HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION/57X
                    2,3HFOR/44X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/44X,29HBASED UPON
                    3INITIAL CONDITIONS///15X,17HSAMPLE NUMBERS : ,3X,8(3A4))
ISN 0061             WRITE(6,211)TEMP,(DATE(K),K=1,5)
ISN 0062         211 FORMAT(//26X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,7
                    1HDATE : ,5A4)
```

```
ISN 0063            WRITE(6,212)
ISN 0064        212 FORMAT(////80X,9HSTIFFNESS,21X,4HUNIT/56X,6HSTRESS,6X,6HSTRAIN,8X,
                   16HOF MIX,8X,4HTIME,9X,6HWEIGHT/57X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI)
                   2,7X,9H(SECONDS),5X,8H(P.C.F.))
ISN 0065            WRITE(6,213) XBAR5,XBAR6,IXBAR7,XBAR8,XBAR9
ISN 0066        213 FORMAT(//23X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,3X,F10.1,7X,F7.2/)
ISN 0067            WRITE(6,214) SIGMA5,SIGMA6,ISGMA7,SIGMA8,SIGMA9
ISN 0068        214 FORMAT(23X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,3X,F10.1,
                   17X,F7.2/)
ISN 0069            WRITE(6,215) VAR5,VAR6,VAR7,VAR8,VAR9
ISN 0070        215 FORMAT(23X,28HCOEFFICIENT OF VARIATION (%),2X,F9.2,3X,F8.2,7X,F8.2
                   1,3X,F10.2,7X,F7.2///)
              C
              C
              C        SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
              C        DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
              C        BASED UPON FAILURE CONDITIONS .
              C
              C
ISN 0071            CALL STATS(N,FLSTRS,XBAR1,SIGMA1,VAR1)
ISN 0072            CALL STATS(N,FLSTRN,XBAR2,SIGMA2,VAR2)
ISN 0073            CALL STATS(N,FLSTFF,XBAR3,SIGMA3,VAR3)
ISN 0074            CALL STATS(N,FLTIME,XBAR4,SIGMA4,VAR4)
ISN 0075            IXBAR3=XBAR3
ISN 0076            ISGMA3=SIGMA3
ISN 0077            WRITE(6,250)(TITLE(K),K=1,20),NN,NN,N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0078        250 FORMAT(1H1//////29X,20A4//91X,      5HPAGE ,I2,4H OF ,I2///29X,
                   159HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION/57X
                   2,3HFOR/44X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/44X,29HBASED UPON
                   3FAILURE CONDITIONS///15X,17HSAMPLE NUMBERS : ,3X,8(3A4))
ISN 0079            WRITE(6,251)TEMP,(DATE(K),K=1,5)
ISN 0080        251 FORMAT(//26X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,
                   1HDATE : ,5A4)
ISN 0081            WRITE(6,252)
ISN 0082        252 FORMAT(////80X,9HSTIFFNESS,21X,4HUNIT/56X,6HSTRESS,6X,6HSTRAIN,8X,
                   16HOF MIX,8X,4HTIME,9X,6HWEIGHT/57X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI)
                   2,7X,9H(SECONDS),5X,8H(P.C.F.))
ISN 0083            WRITE(6,253) XBAR1,XBAR2,IXBAR3,XBAR4,XBAR9
ISN 0084        253 FORMAT(//23X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,3X,F10.1,7X,F7.2/)
ISN 0085            WRITE(6,254) SIGMA1,SIGMA2,ISGMA3,SIGMA4,SIGMA9
ISN 0086        254 FORMAT(23X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,3X,F10.1,
                   17X,F7.2/)
ISN 0087            WRITE(6,255) VAR1,VAR2,VAR3,VAR4,VAR9
ISN 0088        255 FORMAT(23X,28HCOEFFICIENT OF VARIATION (%),2X,F9.2,3X,F8.2,7X,F8.2
                   1,3X,F10.2,7X,F7.2///)
ISN 0089        300 CONTINUE
ISN 0090            WRITE(6,310)
ISN 0091        310 FORMAT(1H1)
ISN 0092            STOP
ISN 0093            END

***** END OF COMPILATION ******
```

```
ISN 0002          SUBROUTINE MAX(L,ARRAY,NNN)
ISN 0003          DIMENSION ARRAY(50)
ISN 0004          AMAX=ARRAY(1)
ISN 0005          NNN=1
ISN 0006          DO 20 I=2,L
ISN 0007          IF(ARRAY(I) .GT. AMAX) GO TO 10
ISN 0009          GO TO 20
ISN 0010       10 NNN=I
ISN 0011          AMAX=ARRAY(I)
ISN 0012       20 CONTINUE
ISN 0013          RETURN
ISN 0014          END

****** END OF COMPILATION ******
```

```
ISN 0002          SUBROUTINE STATS(N,X,XBAR,SIGMA,VAR)
ISN 0003          DIMENSION X(50)
ISN 0004          SUM=0.
ISN 0005          DO 10 I=1,N
ISN 0006          SUM=SUM+X(I)
ISN 0007       10 CONTINUE
ISN 0008          AN=N
ISN 0009          BN=N-1
ISN 0010          XBAR=SUM/AN
ISN 0011          SMSQDF=0.
ISN 0012          DO 20 I=1,N
ISN 0013          SMSQDF=SMSQDF+(X(I)-XBAR)**2
ISN 0014       20 CONTINUE
ISN 0015          SIGMA=(SMSQDF/BN)**0.5
ISN 0016          VAR=SIGMA/XBAR*100.
ISN 0017          RETURN
ISN 0018          END

****** END OF COMPILATION ******
```

SUPPLY NUMBER 5268 & WATSONVILLE AGG.   COMPACTION : 75 BLOWS

SAMPLE NUMBER :   SM 21

BULK SPECIFIC GRAVITY OF THE COMPACTED MIXTURE = 2.443

UNIT WEIGHT = 152.4 POUNDS PER CUBIC FOOT

DIAMETER = 4.005 INCHES

THICKNESS = 2.521 INCHES

DETAILS OF TEST

RATE OF LOADING = 0.056 INCHES / MINUTE   TIME TO FRACTURE = 161 SECONDS

TEST TEMPERATURE : 0 DEGREES FAHRENHEIT   DATE :   MAY 1 , 1969

STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)
182.85	0.000100	3335248	95
277.43	0.000200	2530187	120
302.65	0.000300	1840135	138
378.32	0.000400	1725129	150
416.15	0.000500	1518113	156
441.37	0.001000	805059	161

SUPPLY NUMBER 5268 & WATSONVILLE AGG.   COMPACTION : 75 BLOWS

MEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION
FOR
THE 5 SAMPLES IN THIS SERIES
BASED UPON INITIAL CONDITIONS

SAMPLE NUMBERS : SM 21 SM 22 SM 23 SM 24 SM 25

TEST TEMPERATURE : 0 DEGREES FAHRENHEIT   DATE : MAY 1 , 1969

	STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)	UNIT WEIGHT (P.C.F.)
MEAN	168.48	0.000120	2715001	101.4	153.34
STANDARD DEVIATION	31.67	0.000045	721017	25.1	0.95
COEFFICIENT OF VARIATION (%)	18.80	37.27	26.55	24.75	0.62

SUPPLY NUMBER 5268 & WATSONVILLE AGG.   COMPACTION : 75 BLOWS

MEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION
FOR
THE 5 SAMPLES IN THIS SERIES
BASED UPON FAILURE CONDITIONS

SAMPLE NUMBERS : SM 21 SM 22 SM 23 SM 24 SM 25

TEST TEMPERATURE : 0 DEGREES FAHRENHEIT   DATE : MAY 1 , 1969

	STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)	UNIT WEIGHT (P.C.F.)
MEAN	543.67	0.001160	859114	193.0	153.34
STANDARD DEVIATION	67.83	0.000152	97718	24.9	0.95
COEFFICIENT OF VARIATION (%)	12.48	13.07	11.37	12.92	0.62

DETAILED COMPUTER ANALYSIS

```
ISN 0002          DIMENSION TITLE(20),DATE(5),TIME(20),LOAD(20),STRAIN(20),STRESS(20
                 1),FLSTRS(20),FLSTRN(20),FLTIME(20),SAMPLE(20,5),STIFF(20),FLSTFF(2
                 20),ORSTRS(20),ORSTRN(20),ORSTFF(20),ORSBIT(20),UNITWT(20),AIR(22),
                 3AREA(22),WORK(22),VDEF(22),BITST(22),SBIT(22),FLAREA(20),FLBTST(20
                 4),FLSBIT(20),FLWORK(20)
ISN 0003          INTEGER TIME,SAMPLE,FAILTM,TEMP
ISN 0004          REAL LOAD
            C
            C
            C             M = THE NUMBER OF SETS OF SAMPLES TO BE PROCESSED DURING
            C                 THIS RUN .
            C
            C
ISN 0005          READ(5,10)M
ISN 0006       10 FORMAT(I5)
ISN 0007          DO 300 II=1,M
            C
            C
            C         TITLE = A DESCRIPTION (80 COLUMNS OR LESS) TO APPEAR AT THE
            C                 TOP OF EACH PAGE TO IDENTIFY EACH PARTICULAR SET .
            C
            C
ISN 0008          READ(5,20)(TITLE(K),K=1,20)
ISN 0009       20 FORMAT(20A4)
            C
            C
            C          TEMP = THE TEST TEMPERATURE , IN DEGREES FAHRENHEIT , AT
            C                 WHICH THIS SET WAS RUN .
            C
            C          RATE = THE RATE OF LOAD APPLICATION IN INCHES PER MINUTE .
            C
            C          DATE = THE DATE AT WHICH THE SAMPLES WITHIN THIS SET
            C                 WERE TESTED .
            C
            C
ISN 0010          READ(5,30)TEMP,RATE,(DATE(K),K=1,5)
ISN 0011       30 FORMAT(I10,F10.3,5A4)
            C
            C
            C         ACMIX = THE ASPHALT CONTENT OF THE MIX , IN POUNDS OF ASPHALT
            C                 PER ONE HUNDRED POUNDS OF DRY AGGREGATE .
            C
            C          GAGG = THE BULK SPECIFIC GRAVITY OF THE AGGREGATE .
            C
            C           GAC = THE SPECIFIC GRAVITY OF THE ASPHALT CEMENT .
            C
            C          PABS = THE PERCENT ABSORPTION , IN POUNDS OF ASPHALT CEMENT
            C                 ABSORBED PER ONE HUNDRED POUNDS OF DRY AGGREGATE .
            C
            C
ISN 0012          READ(5,35)ACMIX,GAGG,GAC,PABS
ISN 0013       35 FORMAT(40X,4F10.3)
            C
            C
            C             N = THE NUMBER OF SAMPLES WITHIN THIS SET .
            C
            C
```

```
ISN 0014          READ(5,40)N
ISN 0015       40 FORMAT(I5)
ISN 0016          DO 200 I=1,N
            C
            C
            C         SAMPLE = THE IDENTIFICATION NUMBER OF THE SAMPLE .
            C
            C          WTAIR = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN AIR .
            C
            C          WTWAT = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN WATER .
            C
            C           DIAM = THE AVERAGE DIAMETER OF THE SAMPLE , IN INCHES .
            C
            C          THICK = THE AVERAGE THICKNESS OF THE SAMPLE , IN INCHES .
            C
            C              L = THE NUMBER OF LOAD AND STRAIN POINTS PICKED OFF THE
            C                  LOAD AND DEFORMATION STRIP CHART .
            C
            C         FAILTM = THE TIME TO FAILURE , IN SECONDS .
            C
            C
ISN 0017          READ(5,50)(SAMPLE(I,K),K=1,3),WTAIR,WTWAT,DIAM,THICK,L,FAILTM
ISN 0018       50 FORMAT(3A4,F8.3,3F10.3,2I10)
            C
            C
            C           SPGR = BULK SPECIFIC GRAVITY OF THE COMPACTED MIXTURE .
            C
            C
ISN 0019          SPGR=WTAIR/(WTAIR-WTWAT)
ISN 0020          WTAC=100.*SPGR*ACMIX/(100.+ACMIX)
ISN 0021          WTAGG=100.*SPGR-WTAC
ISN 0022          WTABAC=PABS*WTAGG/100.
            C
            C
            C           EFAC = EFFECTIVE ASPHALT CONTENT OF THE MIX IN POUNDS OF
            C                  EFFECTIVE ASPHALT CEMENT PER ONE HUNDRED POUNDS OF
            C                  DRY AGGREGATE .
            C
            C
ISN 0023          EFAC=(WTAC-WTABAC)/WTAGG*100.
ISN 0024          VAGG=WTAGG/GAGG
ISN 0025          VEFAC=(WTAC-WTABAC)/GAC
            C
            C
            C            AIR = AIR VOIDS IN PER CENT .
            C
            C
ISN 0026          AIR(I)=100.-(VAGG+VEFAC)
            C
            C
            C          CSUBV = VOLUME CONCENTRATION OF THE AGGREGATE .
            C
            C          BSUBV = VOLUME CONCENTRATION OF THE ASPHALT CEMENT .
            C
            C
ISN 0027          CSUBV=VAGG/(VAGG+VEFAC)
ISN 0028          BSUBV=1.0-CSUBV
```

```
ISN 0029          CPV=CSUBV/(1.0+0.01*(AIR(I)-3.0))
ISN 0030          CA=CPV/(1.0-CPV)
            C
            C
            C        UNITWT = UNIT WEIGHT OF THE COMPACTED MIXTURE ,
            C                 IN POUNDS PER CUBIC FOOT .
            C
            C
ISN 0031          UNITWT(I)=SPGR*62.4
ISN 0032          LN=N+1
ISN 0033          NN=N+2
ISN 0034          WRITE(6,52)(TITLE(K),K=1,20),I,NN
ISN 0035       52 FORMAT(1H1//////33X,20A4//114X,5HPAGE ,I2,4H OF ,I2//)
ISN 0036          WRITE(6,54)(SAMPLE(I,K),K=1,3),TEMP,(DATE(K),K=1,5)
ISN 0037       54 FORMAT(22X,16HSAMPLE NUMBER : ,3A4,5X,19HTEST TEMPERATURE : ,I3,19
                 1H DEGREES FAHRENHEIT,5X,7HDATE : ,5A4/)
ISN 0038          WRITE(6,56)DIAM,THICK,ACMIX,GAGG,GAC,PABS,EFAC
ISN 0039       56 FORMAT(45X,11HDIAMETER = ,F5.3,7H INCHES,12X,12HTHICKNESS = ,F5.3,
                 17H INCHES//22X,29HASPHALT CONTENT OF THE MIX = ,F4.2,2H %,3X,27HSP
                 2. GR. OF THE AGGREGATE = ,F5.3,3X,25HSP. GR. OF THE ASPHALT = ,F5.
                 33//35X,21HASPHALT ABSORPTION = ,F4.2,2H %,6X,39HEFFECTIVE ASPHALT
                 4CONTENT OF THE MIX = ,F4.2,2H %/)
ISN 0040          WRITE(6,58)SPGR,UNITWT(I),AIR(I)
ISN 0041       58 FORMAT(22X,40HBULK SP. GR. OF THE COMPACTED MIXTURE = ,F5.3,7X,14H
                 1UNIT WEIGHT = ,F5.1,7H P.C.F.,7X,12HAIR VOIDS = ,F5.2,2H %/)
ISN 0042          WRITE(6,60)CSUBV,BSUBV
ISN 0043       60 FORMAT(30X,36HVOLUME CONCENTRATION OF AGGREGATE = ,F5.3,8X,34HVOLU
                 1ME CONCENTRATION OF BITUMEN = ,F5.3/)
ISN 0044          WRITE(6,62)RATE,FAILTM
ISN 0045       62 FORMAT(35X,18HRATE OF LOADING = ,F5.3,16H INCHES / MINUTE,8X,19HTI
                 1ME TO FRACTURE = ,I3,8H SECONDS//)
ISN 0046          WRITE(6,64)
ISN 0047       64 FORMAT(42X,9HSTIFFNESS,20X,9HSTIFFNESS,8X,7HBITUMEN,19X,10HWORK IN
                 1PUT)
ISN 0048          WRITE(6,66)
ISN 0049       66 FORMAT(21X,6HSTRESS ,5X,6HSTRAIN,5X,6HOF MIX,8X,4HTIME,9X,11HOF  B
                 1ITUMEN,7X,6HSTRAIN,4X,9HTOUGHNESS,4X,15HPER UNIT VOLUME)
ISN 0050          WRITE(6,68)
ISN 0051       68 FORMAT(22X,5H(PSI),4X,7H(IN/IN),6X,5H(PSI),6X,9H(SECONDS),4X,5H(PS
                 1I),1X,10H(KG/SQ CM),4X,7H(IN/IN),5X,5H(PSI),8X,13H(IN-LB/CU IN)//)
ISN 0052          DENOM=3.14159*DIAM*THICK
ISN 0053          STRESS(1)=0.0
ISN 0054          STRAIN(1)=0.0
ISN 0055          AREA(1)=0.0
ISN 0056          WORK(1)=0.0
ISN 0057          VDEF(1)=0.0
ISN 0058          LOAD(1)=0.0
            C
            C
            C        TIME = THE TIME , IN SECONDS , FROM ZERO TIME TO EACH OF THE
            C               POINTS ON THE LOAD AND DEFORMATION STRIP CHART .
            C
            C
ISN 0059          L=L+1
ISN 0060          READ(5,70)(TIME(K),K=2,L)
ISN 0061       70 FORMAT(5X,15I5)
            C
```

```
                  C
                  C            LOAD = THE LOAD , IN POUNDS , AT EACH OF THE POINTS ON THE
                  C                   LOAD TRACE .
                  C
                  C
ISN 0062                 READ(5,80)(LOAD(K),K=2,L)
ISN 0063              80 FORMAT(5X,15F5.0)
                  C
                  C
                  C          STRAIN = THE STRAIN , IN TEN THOUSANDTHS OF AN INCH / INCH ,
                  C                   FOR EACH OF THE POINTS ON THE DEFORMATION TRACE .
                  C
                  C
ISN 0064                 READ(5,90)(STRAIN(K),K=2,L)
ISN 0065              90 FORMAT(5X,15F5.0)
ISN 0066                 DO 100 J=2,L
ISN 0067                 STRESS(J)=2.*LOAD(J)/DENOM
ISN 0068                 STRAIN(J)=STRAIN(J)*0.0001
                  C
                  C
                  C          CONSIDERING AVERAGE TENSILE STRESS OVER A ONE INCH GAUGE LENGTH
                  C          AND ASSUMING A POISSONS RATIO OF 0.33 .
                  C
                  C
ISN 0069                 STIFF(J)=0.912*STRESS(J)/(STRAIN(J)*.5)
ISN 0070                 ISTIFF=STIFF(J)
ISN 0071                 ATIME=TIME(J)
                  C
                  C
                  C            AREA = AREA UNDER THE STRESS-STRAIN CURVE , IN PSI .
                  C
                  C
ISN 0072                 AREA(J)=AREA(J-1)+0.5*(STRESS(J-1)+STRESS(J))*(STRAIN(J)-STRAIN(J-
                        1))
ISN 0073                 VDEF(J)=(ATIME/60.)/RATE
                  C
                  C
                  C            WORK = WORK INPUT PER UNIT VOLUME ,
                  C                   IN INCH-POUNDS PER CUBIC INCH .
                  C
                  C
ISN 0074                 WORK(J)=WORK(J-1)+0.5*(LOAD(J)+LOAD(J-1))*(VDEF(J)-VDEF(J-1))/(WTA
                        1IR-WTWAT)*0.061
                  C
                  C
                  C           BITST = BITUMEN STRAIN , IN INCHES PER INCH .
                  C
                  C
ISN 0075                 BITST(J)=STRAIN(J)/BSUBV
ISN 0076                 TRENN=3.0
ISN 0077              91 ENN=TRENN
                  C
                  C
                  C            SBIT = STIFFNESS OF THE BITUMEN ,
                  C                   IN KILOGRAMS PER SQUARE CENTIMETER .
                  C
                  C
```

```
ISN 0078            SBIT(J)=(STIFF(J)/14.223)/((1.0+(2.5/ENN)*CA))**ENN
ISN 0079            CENN=0.83*0.434*ALOG(400000./SBIT(J))
ISN 0080            DIFF=ABS(ENN-CENN)
ISN 0081            IF(DIFF-0.01)94,94,93
ISN 0082         93 TPENN=CENN
ISN 0083            GO TO 91
ISN 0084         94 CONTINUE
ISN 0085            ISTFBT=SBIT(J)
ISN 0086            ISBTLB=SBIT(J)*14.22
ISN 0087            WRITE(6,95)STRESS(J),STRAIN(J),ISTIFF,TIME(J),ISBTLB,ISTFBT,BITST(
                   1J),AREA(J),WORK(J)
ISN 0088         95 FORMAT(20X,F7.2,F11.5,4X,I8,4X,I7,4X,I8,I8,4X,F10.5,F11.4,6X,F9.2/
                   1)
ISN 0089        100 CONTINUE
              C
              C
              C        SUBROUTINE 'MAX' IS CALLED TO DETERMINE THE MAXIMUM SECANT
              C        MODULUS ( THAT IS THE MAXIMUM STIFFNESS OF MIX FOR EACH
              C        STRESS-STRAIN DIAGRAM ) .
              C
              C
ISN 0090            CALL MAX(L,STIFF,NNN)
ISN 0091            ORSTRS(I)=STRESS(NNN)
ISN 0092            ORSTRN(I)=STRAIN(NNN)
ISN 0093            ORSTFF(I)=STIFF(NNN)
ISN 0094            ORSBIT(I)=SBIT(NNN)
ISN 0095            FLSTRS(I)=STRESS(L)
ISN 0096            FLSTRN(I)=STRAIN(L)
ISN 0097            FLSTFF(I)=STIFF(L)
ISN 0098            FLTIME(I)=TIME(L)
ISN 0099            FLAREA(I)=AREA(L)
ISN 0100            FLBTST(I)=BITST(L)
ISN 0101            FLSBIT(I)=SBIT(L)
ISN 0102            FLWORK(I)=WORK(L)
ISN 0103        200 CONTINUE
              C
              C
              C        SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
              C        DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
              C        BASED UPON INITIAL CONDITIONS ( THAT IS THE MAXIMUM SECANT
              C        MODULUS OF EACH STRESS-STRAIN DIAGRAM ) .
              C
              C
ISN 0104            CALL STATS(N,ORSTRS,XBAR5,SIGMA5,VAR5)
ISN 0105            CALL STATS(N,ORSTRN,XBAR6,SIGMA6,VAR6)
ISN 0106            CALL STATS(N,ORSTFF,XBAR7,SIGMA7,VAR7)
ISN 0107            CALL STATS(N,ORSBIT,XBAR8,SIGMA8,VAR8)
ISN 0108            CALL STATS(N,UNITWT,XBAR9,SIGMA9,VAR9)
ISN 0109            CALL STATS(N,AIR,XBARA,SIGMAA,VARA)
ISN 0110            IXBAR7=XBAR7
ISN 0111            ISGMA7=SIGMA7
ISN 0112            IXBAR8=XBAR8
ISN 0113            ISGMA8=SIGMA8
ISN 0114            WRITE(6,210)(TITLE(K),K=1,20),LN,NN
ISN 0115        210 FORMAT(1H1//////33X,20A4//114X,5HPAGE ,I2,4H OF ,I2//)
ISN 0116            IF(N .GT. 6) GO TO 213
ISN 0118        211 CONTINUE
```

```
ISN 0119          WRITE(6,212)N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0120      212 FORMAT(50X,59HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VA
                 1RIATION/78X,3HFOR/65X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/65X,29H
                 2BASED UPON INITIAL CONDITIONS///20X,17HSAMPLE NUMBERS : ,3X,6(3A4)
                 3)
ISN 0121          GO TO 215
ISN 0122      213 CONTINUE
ISN 0123          WRITE(6,214)N,((SAMPLE(I,K),K=1,3),I=1,6),((SAMPLE(I,K),K=1,3),I=7
                 1,N)
ISN 0124      214 FORMAT(50X,59HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VA
                 1RIATION/78X,3HFOR/65X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/65X,29H
                 2BASED UPON INITIAL CONDITIONS///20X,17HSAMPLE NUMBERS : ,3X,6(3A4)
                 3/40X,6(3A4))
ISN 0125      215 CONTINUE
ISN 0126          WRITE(6,216)TEMP,(DATE(K),K=1,5)
ISN 0127      216 FORMAT(//35X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,9X,7
                 1HDATE : ,5A4)
ISN 0128          WRITE(6,217)
ISN 0129      217 FORMAT(////77X,9HSTIFFNESS,6X,9HSTIFFNESS,8X,4HUNIT,8X,3HAIR)
ISN 0130          WRITE(6,218)
ISN 0131      218 FORMAT(53X,6HSTRESS,6X,6HSTRAIN,8X,6HOF MIX,6X,11HOF  BITUMEN,6X,6
                 1HWEIGHT,6X,5HVOIDS)
ISN 0132          WRITE(6,219)
ISN 0133      219 FORMAT(54X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI), 8X,10H(KG/SQ CM),5X,8H
                 1(P.C.F.),6X,3H(%))
ISN 0134          WRITE(6,220) XBAR5,XBAR6,IXBAR7,IXBAR8,XBAR9,XBARA
ISN 0135      220 FORMAT(//20X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,5X,I8,9X,F7.2,6X,F5.2)
ISN 0136          WRITE(6,221) SIGMA5,SIGMA6,ISGMA7,ISGMA8,SIGMA9,SIGMAA
ISN 0137      221 FORMAT(/20X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,5X,I8,9X
                 1,F7.2,6X,F5.2)
ISN 0138          WRITE(6,222) VAR5,VAR6,VAR7,VAR8,VAR9,VARA
ISN 0139      222 FORMAT(/20X,28HCOEFFICIENT OF VARIATION (%),5X,F6.2,5X,F6.2,5X,F10
                 1.2,4X,F10.2,5X,F10.2,2X,F9.2)
            C
            C
            C       SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
            C       DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
            C       BASED UPON FAILURE CONDITIONS .
            C
            C
ISN 0140          CALL STATS(N,FLSTRS,XBAR1,SIGMA1,VAR1)
ISN 0141          CALL STATS(N,FLSTRN,XBAR2,SIGMA2,VAR2)
ISN 0142          CALL STATS(N,FLSTFF,XBAR3,SIGMA3,VAR3)
ISN 0143          CALL STATS(N,FLTIME,XBAR4,SIGMA4,VAR4)
ISN 0144          CALL STATS(N,FLAREA,XBARB,SIGMAB,VARB)
ISN 0145          CALL STATS(N,FLBTST,XBARC,SIGMAC,VARC)
ISN 0146          CALL STATS(N,FLSBIT,XBARD,SIGMAD,VARD)
ISN 0147          CALL STATS(N,FLWORK,XBARE,SIGMAE,VARE)
ISN 0148          IXBAR3=XBAR3
ISN 0149          ISGMA3=SIGMA3
ISN 0150          IXBARD=XBARD
ISN 0151          ISGMAD=SIGMAD
ISN 0152          WRITE(6,250)(TITLE(K),K=1,20),NN,NN
ISN 0153      250 FORMAT(1H1//////33X,20A4//114X,5HPAGE ,I2,4H OF ,I2//)
ISN 0154          IF(N .GT. 6) GO TO 253
ISN 0156      251 CONTINUE
ISN 0157          WRITE(6,252)N,((SAMPLE(I,K),K=1,3),I=1,N)
```

```
ISN 0158        252 FORMAT(50X,59HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VA
                   1RIATION/78X,3HFOR/65X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/65X,29H
                   2BASED UPON FAILURE CONDITIONS///20X,17HSAMPLE NUMBERS : ,3X,6(3A4)
                   3)
ISN 0159            GO TO 255
ISN 0160        253 CONTINUE
ISN 0161            WRITE(6,254)N,((SAMPLE(I,K),K=1,3),I=1,6),((SAMPLE(I,K),K=1,3),I=7
                   1,N)
ISN 0162        254 FORMAT(50X,59HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VA
                   1RIATION/78X,3HFOR/65X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/65X,29H
                   2BASED UPON FAILURE CONDITIONS///20X,17HSAMPLE NUMBERS : ,3X,6(3A4)
                   3/40X,6(3A4))
ISN 0163        255 CONTINUE
ISN 0164            WRITE(6,256)TEMP,(DATE(K),K=1,5)
ISN 0165        256 FORMAT(//35X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,9X,7
                   1HDATE : ,5A4)
ISN 0166            WRITE(6,257)
ISN 0167        257 FORMAT(////78X,9HSTIFFNESS,24X,4HUNIT,7X,3HAIR)
ISN 0168            WRITE(6,258)
ISN 0169        258 FORMAT(53X,6HSTRESS,7X,6HSTRAIN,7X,7HOF  MIX,10X,4HTIME,10X,6HWEIG
                   1HT,5X,5HVOIDS)
ISN 0170            WRITE(6,259)
ISN 0171        259 FORMAT(54X,5H(PSI),7X,7H(IN/IN),7X,5H(PSI),9X,9H(SECONDS),6X,8H(P.
                   1C.F.),5X,3H(%))
ISN 0172            WRITE(6,260) XBAR1,XBAR2,IXBAR3,XBAR4,XBAR9,XBARA
ISN 0173        260 FORMAT(//20X,4HMEAN,28X,F7.2,4X,F10.6,5X,I8,9X,F5.1,8X,F7.2,5X,F5.
                   12)
ISN 0174            WRITE(6,261) SIGMA1,SIGMA2,ISGMA3,SIGMA4,SIGMA9,SIGMAA
ISN 0175        261 FORMAT(/20X,18HSTANDARD DEVIATION,14X,F7.2,4X,F10.6,5X,I8,9X,F6.1,
                   18X,F7.2,5X,F5.2)
ISN 0176            WRITE(6,262) VAR1,VAR2,VAR3,VAR4,VAR9,VARA
ISN 0177        262 FORMAT(/20X,28HCOEFFICIENT OF VARIATION (%),4X,F7.2,6X,F6.2,9X,F6.
                   12,9X,F6.2,9X,F6.2,4X,F6.2)
ISN 0178            WRITE(6,263)
ISN 0179        263 FORMAT(///78X,9HSTIFFNESS,6X,10HWORK INPUT)
ISN 0180            WRITE(6,264)
ISN 0181        264 FORMAT(66X,7HBITUMEN,8X,2HOF,14X,3HPER)
ISN 0182            WRITE(6,265)
ISN 0183        265 FORMAT(52X,9HTOUGHNESS,6X,6HSTRAIN,6X,7HBITUMEN,7X,11HUNIT VOLUME)
ISN 0184            WRITE(6,266)
ISN 0185        266 FORMAT(54X,5H(PSI),7X,7H(IN/IN),5X,10H(KG/SQ CM),4X,13H(IN-LB/CU I
                   1N))
ISN 0186            WRITE(6,267) XBARB,XBARC,IXBARD,XBARE
ISN 0187        267 FORMAT(//20X,4HMEAN,28X,F8.4,3X,F10.6,4X,I8,9X,F7.2)
ISN 0188            WRITE(6,268) SIGMAB,SIGMAC,ISGMAD,SIGMAE
ISN 0189        268 FORMAT(/20X,18HSTANDARD DEVIATION,14X,F8.4,3X,F10.6,4X,I8,9X,F7.2)
ISN 0190            WRITE(6,269) VARB,VARC,VARD,VARE
ISN 0191        269 FORMAT(/20X,28HCOEFFICIENT OF VARIATION (%),6X,F6.2,5X,F6.2,9X,F6.
                   12,9X,F6.2)
ISN 0192        300 CONTINUE
ISN 0193            WRITE(6,310)
ISN 0194        310 FORMAT(1H1)
ISN 0195            STOP
ISN 0196            END

****** END OF COMPILATION ******
```

```
  ISN 0002              SUBROUTINE MAX(L,ARRAY,NNN)
  ISN 0003              DIMENSION ARRAY(50)
  ISN 0004              AMAX=ARRAY(2)
  ISN 0005              NNN=2
  ISN 0006              DO 20 I=3,L
  ISN 0007              IF(ARRAY(I) .GT. AMAX) GO TO 10
  ISN 0009              GO TO 20
  ISN 0010           10 NNN=I
  ISN 0011              AMAX=ARRAY(I)
  ISN 0012           20 CONTINUE
  ISN 0013              RETURN
  ISN 0014              END

***** END OF COMPILATION ******
```

```
  ISN 0002              SUBROUTINE STATS(N,X,XBAR,SIGMA,VAR)
  ISN 0003              DIMENSION X(50)
  ISN 0004              SUM=0.
  ISN 0005              DO 10 I=1,N
  ISN 0006              SUM=SUM+X(I)
  ISN 0007           10 CONTINUE
  ISN 0008              AN=N
  ISN 0009              BN=N-1
  ISN 0010              XBAR=SUM/AN
  ISN 0011              SMSQDF=0.
  ISN 0012              DO 20 I=1,N
  ISN 0013              SMSQDF=SMSQDF+(X(I)-XBAR)**2
  ISN 0014           20 CONTINUE
  ISN 0015              SIGMA=(SMSQDF/BN)**0.5
  ISN 0016              VAR=SIGMA/XBAR*100.
  ISN 0017              RETURN
  ISN 0018              END

***** END OF COMPILATION ******
```

SUPPLY NUMBER 5268 & WATSONVILLE AGG. COMPACTION : 75 BLOWS

SAMPLE NUMBER : SM 21 TEST TEMPERATURE : 0 DEGREES FAHRENHEIT DATE : MAY 1 , 1969

DIAMETER = 4.005 INCHES THICKNESS = 2.521 INCHES

ASPHALT CONTENT OF THE MIX = 6.00 % SP. GR. OF THE AGGREGATE = 2.840 SP. GR. OF THE ASPHALT = 1.010

ASPHALT ABSORPTION = 0.0 % EFFECTIVE ASPHALT CONTENT OF THE MIX = 6.00 %

BULK SP. GR. OF THE COMPACTED MIXTURE = 2.443 UNIT WEIGHT = 152.4 P.C.F. AIR VOIDS = 5.17 %

VOLUME CONCENTRATION OF AGGREGATE = 0.856 VOLUME CONCENTRATION OF BITUMEN = 0.144

RATE OF LOADING = 0.056 INCHES / MINUTE TIME TO FRACTURE = 161 SECONDS

STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)	STIFFNESS OF BITUMEN (PSI)	STIFFNESS OF BITUMEN (KG/SQ CM)	BITUMEN STRAIN (IN/IN)	TOUGHNESS (PSI)	WORK INPUT PER UNIT VOLUME (IN-LB/CU IN)
182.85	0.00010	3335248	95	141581	9956	0.00069	0.0091	4.86
277.43	0.00020	2530187	120	80796	5681	0.00139	0.0322	8.08
302.65	0.00030	1840135	138	44284	3114	0.00208	0.0612	11.01
378.32	0.00040	1725129	150	39498	2777	0.00277	0.0952	13.29
416.15	0.00050	1518113	156	31594	2221	0.00346	0.1349	14.63
441.37	0.00100	805059	161	10907	767	0.00693	0.3493	15.83

SUPPLY NUMBER 5268 & WATSONVILLE AGG. COMPACTION : 75 BLOWS

MEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION
FOR
THE 5 SAMPLES IN THIS SERIES
BASED UPON INITIAL CONDITIONS

SAMPLE NUMBERS : SM 21 SM 22 SM 23 SM 24 SM 25

TEST TEMPERATURE : 0 DEGREES FAHRENHEIT DATE : MAY 1 , 1969

	STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	STIFFNESS OF BITUMEN (KG/SQ CM)	UNIT WEIGHT (P.C.F.)	AIR VOIDS (%)
MEAN	168.48	0.000120	2715001	6382	153.34	4.60
STANDARD DEVIATION	31.67	0.000045	721017	3145	0.95	0.59
COEFFICIENT OF VARIATION (%)	18.80	37.27	26.56	49.28	0.62	12.92

SUPPLY NUMBER 5268 & WATSONVILLE AGG.   COMPACTION : 75 BLOWS

MEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION
FOR
THE 5 SAMPLES IN THIS SERIES
BASED UPON FAILURE CONDITIONS

SAMPLE NUMBERS : SM 21 SM 22 SM 23 SM 24 SM 25

TEST TEMPERATURE : 0 DEGREES FAHRENHEIT   DATE : MAY 1 , 1969

	STRESS (PSI)	STRAIN (IN/IN)	STIFFNESS OF MIX (PSI)	TIME (SECONDS)	UNIT WEIGHT (P.C.F.)	AIR VOIDS (%)
MEAN	543.67	0.001160	859114	193.0	153.34	4.60
STANDARD DEVIATION	67.83	0.000152	97718	24.9	0.95	0.59
COEFFICIENT OF VARIATION (%)	12.48	13.07	11.37	12.92	0.62	12.92

	TOUGHNESS (PSI)	BITUMEN STRAIN (IN/IN)	STIFFNESS OF BITUMEN (KG/SQ CM)	WORK INPUT PER UNIT VOLUME (IN-LB/CU IN)
MEAN	0.4798	0.008036	764	21.19
STANDARD DEVIATION	0.1173	0.001051	110	3.94
COEFFICIENT OF VARIATION (%)	24.44	13.07	14.44	18.61

COMPUTER ANALYSIS WITH STRESS-STRAIN PLOT

```
ISN 0002           DIMENSION TITLE(20),DATE(5),TIME(20),LOAD(20),STRAIN(22),STRESS(22
                  1),FLSTRS(20),FLSTRN(20),FLTIME(20),SAMPLE(20,3),STIFF(20),FLSTFF(2
                  20),ORSTRS(20),ORSTRN(20),ORSTFF(20),ORTIME(20),UNITWT(20),BUF(2048
                  3),TITLE1(10),TITLE2(10),SAM(3)
ISN 0003           INTEGER TIME,SAMPLE,FAILTM,TEMP
ISN 0004           REAL LOAD,MAXSTR
ISN 0005           CALL PLOTS(BUF,8192)
ISN 0006           IX=0
ISN 0007           III=0
             C
             C
             C              M = THE NUMBER OF SETS OF SAMPLES TO BE PROCESSED DURING
             C                  THIS RUN .
             C
             C
ISN 0008           READ(5,10)M
ISN 0009        10 FORMAT(I5)
ISN 0010           DO 300 II=1,M
             C
             C
             C          TITLE = A DESCRIPTION (80 COLUMNS OR LESS) TO APPEAR AT THE
             C                  TOP OF EACH PAGE TO IDENTIFY EACH PARTICULAR SET .
             C
             C
ISN 0011           READ(5,20)(TITLE(K),K=1,20)
ISN 0012        20 FORMAT(20A4)
             C
             C
             C           TEMP = THE TEST TEMPERATURE , IN DEGREES FAHRENHEIT , AT
             C                  WHICH THIS SET WAS RUN .
             C
             C           RATE = THE RATE OF LOAD APPLICATION IN INCHES PER MINUTE .
             C
             C           DATE = THE DATE AT WHICH THE SAMPLES WITHIN THIS SET
             C                  WERE TESTED .
             C
             C
ISN 0013           READ(5,30)TEMP,RATE,(DATE(K),K=1,5)
ISN 0014        30 FORMAT(7X,I3,F10.3,5A4)
             C
             C
             C         MAXSTR = THE MAXIMUM STRAIN , IN TEN THOUSANDTHS OF AN INCH ,
             C                  TO BE EXPECTED WITHIN THIS RUN . THIS IS REQUIRED TO
             C                  ESTABLISH THE CORRECT SCALE FOR STRAIN ON THE CALCOMP
             C                  PLOTTER . THIS MAY BE ANY VALUE , BUT THE FOLLOWING
             C                  VALUES WILL PRODUCE CONVENIENT SCALES .
             C
             C
             C                  MAXSTR                         SCALE
             C
             C                    10       1" =  2 TEN THOUSANDS OF AN INCH / INCH
             C                    25       1" =  5 TEN THOUSANDS OF AN INCH / INCH
             C                    50       1" = 10 TEN THOUSANDS OF AN INCH / INCH
             C                   100       1" = 20 TEN THOUSANDS OF AN INCH / INCH
             C
             C
ISN 0015           READ(5,35)MAXSTR
```

```
ISN 0016        35 FORMAT(F10.0)
           C
           C
           C            N = THE NUMBER OF SAMPLES WITHIN THIS SET .
           C
           C
ISN 0017           READ(5,40)N
ISN 0018        40 FORMAT(I5)
ISN 0019           DO 200 I=1,N
           C
           C
           C         SAMPLE = THE IDENTIFICATION NUMBER OF THE SAMPLE .
           C
           C          WTAIR = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN AIR .
           C
           C          WTWAT = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN WATER .
           C
           C           DIAM = THE AVERAGE DIAMETER OF THE SAMPLE , IN INCHES .
           C
           C          THICK = THE AVERAGE THICKNESS OF THE SAMPLE , IN INCHES .
           C
           C              L = THE NUMBER OF LOAD AND STRAIN POINTS PICKED OFF THE
           C                  LOAD AND DEFORMATION STRIP CHART .
           C
           C         FAILTM = THE TIME TO FAILURE , IN SECONDS .
           C
           C
ISN 0020           READ(5,50)(SAMPLE(I,K),K=1,3),WTAIR,WTWAT,DIAM,THICK,L,FAILTM
ISN 0021        50 FORMAT(3A4,F8.3,3F10.3,2I10)
           C
           C
           C           SPGR = BULK SPECIFIC GRAVITY OF THE COMPACTED MIXTURE .
           C
           C
ISN 0022           SPGR=WTAIR/(WTAIR-WTWAT)
           C
           C
           C         UNITWT = UNIT WEIGHT OF THE COMPACTED MIXTURE ,
           C                  IN POUNDS PER CUBIC FOOT .
           C
           C
ISN 0023           UNITWT(I)=SPGR*62.4
ISN 0024           LN=N+1
ISN 0025           NN=N+2
ISN 0026           WRITE(6,60)(TITLE(K),K=1,20),I,NN,(SAMPLE(I,K),K=1,3),SPGR,UNITWT(
                  1I),DIAM,THICK
ISN 0027        60 FORMAT(1H1//////20X,20A4//91X,       5HPAGE ,I2,4H OF ,I2///44X,17H
                  1SAMPLE NUMBER :  ,3A4//32X,     49HBULK SPECIFIC GRAVITY OF THE COM
                  2PACTED MIXTURE = ,      F5.3//38X,14HUNIT WEIGHT = ,F5.1,22H POUNDS
                  2 PER CUBIC FOOT ,               //45X,11HDIAMETER = ,    F5.3,7H INCHES/
                  3/44X,12HTHICKNESS = ,      F5.3,7H INCHES//)
ISN 0028           WRITE(6,61) RATE,FAILTM,TEMP,(DATE(K),K=1,5)
ISN 0029        61 FORMAT(25X,15HDETAILS OF TEST//26X,18HRATE OF LOADING = ,F5.3,16H
                  1INCHES / MINUTE,4X,19HTIME TO FRACTURE = ,I3,8H SECONDS//26X,19HTE
                  2ST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,9HDATE :    ,5A4///)
ISN 0030           WRITE(6,62)
ISN 0031        62 FORMAT(60X,9HSTIFFNESS/30X,6HSTRESS,9X,6HSTRAIN,11X,6HOF MIX,10X,
```

```
                     14HTIME/31X,5H(PSI),9X,7H(IN/IN),10X,5H(PSI),9X,9H(SECONDS)///)
ISN 0032              DENOM=3.14159*DIAM*THICK
                C
                C
                C          TIME = THE TIME , IN SECONDS , FROM ZERO TIME TO EACH OF THE
                C                 POINTS ON THE LOAD AND DEFORMATION STRIP CHART .
                C
                C
ISN 0033              L=L+1
ISN 0034              READ(5,70)(TIME(K),K=2,L)
ISN 0035           70 FORMAT(5X,15I5)
                C
                C
                C          LOAD = THE LOAD , IN POUNDS , AT EACH OF THE POINTS ON THE
                C                 LOAD TRACE .
                C
                C
ISN 0036              READ(5,80)(LOAD(K),K=2,L)
ISN 0037           80 FORMAT(5X,15F5.0)
                C
                C
                C        STRAIN = THE STRAIN , IN TEN THOUSANDTHS OF AN INCH / INCH ,
                C                 FOR EACH OF THE POINTS ON THE DEFORMATION TRACE .
                C
                C
ISN 0038              STRESS(1)=0.0
ISN 0039              STRAIN(1)=0.0
ISN 0040              READ(5,90)(STRAIN(K),K=2,L)
ISN 0041           90 FORMAT(5X,15F5.0)
ISN 0042              DO 100 J=2,L
ISN 0043              STRESS(J)=2.*LOAD(J)/DENOM
ISN 0044              STRAIN(J)=STRAIN(J)*0.0001
                C
                C
                C        CONSIDERING AVERAGE TENSILE STRESS OVER A ONE INCH GAUGE LENGTH
                C        AND ASSUMING A POISSONS RATIO OF 0.33 .
                C
                C
ISN 0045              STIFF(J)=0.912*STRESS(J)/(STRAIN(J)*.5)
ISN 0046              ISTIFF=STIFF(J)
ISN 0047              WRITE(6,95)STRESS(J),STRAIN(J),ISTIFF,TIME(J)
ISN 0048           95 FORMAT(26X,F10.2,6X,F10.6,8X,I8,9X,I5/)
ISN 0049          100 CONTINUE
ISN 0050              FTEMP=TEMP
                C
                C
                C        SUBROUTINE 'GRAPH' IS CALLED SO THAT THE VALUES REQUIRED FOR
                C        THE CALCOMP PLOTTING OF STRESS VERSUS STRAIN CAN BE STORED
                C        ON THE 7 TRACK PLOTTING TAPE .
                C
                C
ISN 0051              CALL GRAPH(BUF,STRESS,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXSTR,N,II
                     1,III, XBAR1,XBAR2)
                C
                C
                C        SUBROUTINE 'MAX' IS CALLED TO DETERMINE THE MAXIMUM SECANT
                C        MODULUS ( THAT IS THE MAXIMUM STIFFNESS OF MIX FOR EACH
```

```
                  C          STRESS-STRAIN DIAGRAM ) .
                  C
                  C
ISN 0052                CALL MAX(L,STIFF,NNN)
ISN 0053                ORSTRS(I)=STRESS(NNN)
ISN 0054                ORSTRN(I)=STRAIN(NNN)
ISN 0055                ORSTFF(I)=STIFF(NNN)
ISN 0056                ORTIME(I)=TIME(NNN)
ISN 0057                FLSTRS(I)=STRESS(L)
ISN 0058                FLSTRN(I)=STRAIN(L)
ISN 0059                FLSTFF(I)=STIFF(L)
ISN 0060                FLTIME(I)=TIME(L)
ISN 0061            200 CONTINUE
                  C
                  C
                  C          SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
                  C          DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
                  C          BASED UPON INITIAL CONDITIONS ( THAT IS THE MAXIMUM SECANT
                  C          MODULUS OF EACH STRESS-STRAIN DIAGRAM ) .
                  C
                  C
ISN 0062                CALL STATS(N,ORSTRS,XBAR5,SIGMA5,VAR5)
ISN 0063                CALL STATS(N,ORSTRN,XBAR6,SIGMA6,VAR6)
ISN 0064                CALL STATS(N,ORSTFF,XBAR7,SIGMA7,VAR7)
ISN 0065                CALL STATS(N,ORTIME,XBAR8,SIGMA8,VAR8)
ISN 0066                CALL STATS(N,UNITWT,XBAR9,SIGMA9,VAR9)
ISN 0067                IXBAR7=XBAR7
ISN 0068                ISGMA7=SIGMA7
ISN 0069                WRITE(6,210)(TITLE(K),K=1,20),LN,NN,N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0070            210 FORMAT(1H1//////20X,20A4//91X,        5HPAGE ,I2,4H OF ,I2///29X,
                       159HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION/57X
                       2,3HFOR/44X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/44X,29HBASED UPON
                       3INITIAL CONDITIONS///15X,17HSAMPLE NUMBERS : ,3X,8(3A4))
ISN 0071                WRITE(6,211)TEMP,(DATE(K),K=1,5)
ISN 0072            211 FORMAT(//26X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,7
                       1HDATE : ,5A4)
ISN 0073                WRITE(6,212)
ISN 0074            212 FORMAT(////80X,9HSTIFFNESS,21X,4HUNIT/56X,6HSTRESS,6X,6HSTRAIN,8X,
                       16HOF MIX,8X,4HTIME,9X,6HWEIGHT/57X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI)
                       2,7X,9H(SECONDS),5X,8H(P.C.F.))
ISN 0075                WRITE(6,213) XBAR5,XBAR6,IXBAR7,XBAR8,XBAR9
ISN 0076            213 FORMAT(//23X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,3X,F10.1,7X,F7.2/)
ISN 0077                WRITE(6,214) SIGMA5,SIGMA6,ISGMA7,SIGMA8,SIGMA9
ISN 0078            214 FORMAT(23X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,3X,F10.1,
                       17X,F7.2/)
ISN 0079                WRITE(6,215) VAR5,VAR6,VAR7,VAR8,VAR9
ISN 0080            215 FORMAT(23X,28HCOEFFICIENT OF VARIATION (%),2X,F9.2,3X,F8.2,7X,F8.2
                       1,3X,F10.2,7X,F7.2///)
                  C
                  C
                  C          SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
                  C          DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
                  C          BASED UPON FAILURE CONDITIONS .
                  C
                  C
ISN 0081                CALL STATS(N,FLSTRS,XBAR1,SIGMA1,VAR1)
ISN 0082                CALL STATS(N,FLSTRN,XBAR2,SIGMA2,VAR2)
```

```
ISN 0083          CALL STATS(N,FLSTFF,XBAR3,SIGMA3,VAR3)
ISN 0084          CALL STATS(N,FLTIME,XBAR4,SIGMA4,VAR4)
ISN 0085          IXBAR3=XBAR3
ISN 0086          ISGMA3=SIGMA3
ISN 0087          III=III+1
ISN 0088          CALL GRAPH(BUF,STRESS,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXSTR,N,II
                 1,III, XBAR1,XBAR2)
ISN 0089          WRITE(6,250)(TITLE(K),K=1,20),NN,NN,N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0090      250 FORMAT(1H1//////20X,20A4//91X,      5HPAGE ,I2,4H OF ,I2///29X,
                 159HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION/57X
                 2,3HFOR/44X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/44X,29HBASED UPON
                 3FAILURE CONDITIONS///15X,17HSAMPLE NUMBERS : ,3X,8(3A4))
ISN 0091          WRITE(6,251)TEMP,(DATE(K),K=1,5)
ISN 0092      251 FORMAT(//26X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,7
                 1HDATE : ,5A4)
ISN 0093          WRITE(6,252)
ISN 0094      252 FORMAT(////80X,9HSTIFFNESS,21X,4HUNIT/56X,6HSTRESS,6X,6HSTRAIN,8X,
                 16HOF MIX,8X,4HTIME,9X,6HWEIGHT/57X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI)
                 2,7X,9H(SECONDS),5X,8H(P.C.F.))
ISN 0095          WRITE(6,253) XBAR1,XBAR2,IXBAR3,XBAR4,XBAR9
ISN 0096      253 FORMAT(//23X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,3X,F10.1,7X,F7.2/)
ISN 0097          WRITE(6,254) SIGMA1,SIGMA2,ISGMA3,SIGMA4,SIGMA9
ISN 0098      254 FORMAT(23X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,3X,F10.1,
                 17X,F7.2/)
ISN 0099          WRITE(6,255) VAR1,VAR2,VAR3,VAR4,VAR9
ISN 0100      255 FORMAT(23X,28HCOEFFICIENT OF VARIATION (%),2X,F9.2,3X,F8.2,7X,F8.2
                 1,3X,F10.2,7X,F7.2///)
ISN 0101      300 CONTINUE
ISN 0102          CALL PLOT(0.0,0.0,999)
ISN 0103          WRITE(6,310)
ISN 0104      310 FORMAT(1H1)
ISN 0105          STOP
ISN 0106          END
DCONS FOR EXTERNAL REFERENCES

***** END OF COMPILATION ******
```

```
ISN 0002          SUBROUTINE MAX(L,ARRAY,NNN)
ISN 0003          DIMENSION ARRAY(50)
ISN 0004          AMAX=ARRAY(2)
ISN 0005          NNN=2
ISN 0006          DO 20 I=3,L
ISN 0007          IF(ARRAY(I) .GT. AMAX) GO TO 10
ISN 0009          GO TO 20
ISN 0010       10 NNN=I
ISN 0011          AMAX=ARRAY(I)
ISN 0012       20 CONTINUE
ISN 0013          RETURN
ISN 0014          END

***** END OF COMPILATION ******
```

```
ISN 0002          SUBROUTINE STATS(N,X,XBAR,SIGMA,VAR)
ISN 0003          DIMENSION X(50)
ISN 0004          SUM=0.
ISN 0005          DO 10 I=1,N
ISN 0006          SUM=SUM+X(I)
ISN 0007       10 CONTINUE
ISN 0008          AN=N
ISN 0009          BN=N-1
ISN 0010          XBAR=SUM/AN
ISN 0011          SMSQDF=0.
ISN 0012          DO 20 I=1,N
ISN 0013          SMSQDF=SMSQDF+(X(I)-XBAR)**2
ISN 0014       20 CONTINUE
ISN 0015          SIGMA=(SMSQDF/BN)**0.5
ISN 0016          VAR=SIGMA/XBAR*100.
ISN 0017          RETURN
ISN 0018          END

***** END OF COMPILATION ******
```

```
ISN 0002        SUBROUTINE GRAPH(BUF,STRESS,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXST
               1R,N,II,III,XBAR1,XBAR2)
ISN 0003        DIMENSION STRESS(22),STRAIN(22),TITLE(20),SAMPLE(20,3),TITLE1(10),
               1TITLE2(10),SAM(3)
ISN 0004        REAL MAXSTR
ISN 0005        STRESS(L+1)=0.0
ISN 0006        STRAIN(L+1)=0.0
ISN 0007        STRESS(L+2)=100.0
ISN 0008        STRAIN(L+2)=MAXSTR*0.0001/5.0
ISN 0009        IF(I .GT. 1) GO TO 50
ISN 0011        CALL RECT(0.0,0.0,11.0,8.5,0.0,3)
ISN 0012        CALL PLOT(2.5,2.5,-3)
ISN 0013        CALL AXIS(0.0,0.0,'STRAIN , IN/IN',-14,5.0,0.0,STRAIN(L+1),STRAIN(
               1L+2),10.0)
ISN 0014        CALL AXIS(0.0,0.0,'TENSILE STRESS , PSI',20,7.0,90.0,STRESS(L+1),S
               1TRESS(L+2),20.0)
ISN 0015        CALL PLOT(5.0,0.0,3)
ISN 0016        CALL PLOT(5.0,7.0,2)
ISN 0017        CALL PLOT(0.0,7.0,2)
ISN 0018        X=0.0
ISN 0019        DO 1 J=1,6
ISN 0020        CALL SYMBOL(X,7.0,0.10,13,0.0,-1)
ISN 0021        X=X+1.0
ISN 0022      1 CONTINUE
ISN 0023        Y=0.0
ISN 0024        DO 2 J=1,15
ISN 0025        CALL SYMBOL(5.0,Y,0.10,13,90.0,-1)
ISN 0026        Y=Y+0.5
ISN 0027      2 CONTINUE
ISN 0028        DO 3 J=1,10
ISN 0029        TITLE1(J)=TITLE(J)
ISN 0030      3 CONTINUE
ISN 0031        K=0
ISN 0032        DO 5 J=11,20
ISN 0033        K=K+1
ISN 0034        TITLE2(K)=TITLE(J)
ISN 0035      5 CONTINUE
ISN 0036        CALL SYMBOL(0.5,6.8,0.12,TITLE1,0.0,40)
ISN 0037        CALL SYMBOL(0.5,6.6,0.12,TITLE2,0.0,40)
ISN 0038        CALL SYMBOL(1.5,6.4,0.10,19HTEST TEMPERATURE : ,0.0,19)
ISN 0039        CALL NUMBER(3.4,6.4,0.10,FTEMP,0.0,-1)
ISN 0040        CALL SYMBOL(3.7,6.4,0.10,1HF,0.0,1)
ISN 0041        IF (STRESS(L) .GT. 400.) GO TO 30
ISN 0043        Y1=6.0
ISN 0044        Y2=5.8
ISN 0045        Y3=5.5
ISN 0046        Y4=5.25
ISN 0047        Y5=5.0
ISN 0048        GO TO 40
ISN 0049     30 CONTINUE
ISN 0050        AN=N
ISN 0051        Y1=AN*0.2+1.0
ISN 0052        Y2=Y1-0.2
ISN 0053        Y3=Y2-0.3
ISN 0054        Y4=Y3-0.25
```

```
ISN 0055            Y5=Y4-0.25
ISN 0056         40 CONTINUE
ISN 0057            CALL SYMBOL(2.9,Y3,0.12,6HLEGEND,0.0,6)
ISN 0058            CALL SYMBOL(2.2,Y4,0.10,24HSYMBOL      SAMPLE NUMBER,0.0,24)
ISN 0059            Y=Y5
ISN 0060         50 CONTINUE
ISN 0061            IF(II .EQ. III) GO TO 100
ISN 0063            DO 7 J=1,3
ISN 0064            SAM(J)=SAMPLE(I,J)
ISN 0065          7 CONTINUE
ISN 0066            ISYMBL=I+127
ISN 0067            CALL LINE(STRAIN,STRESS,L,1,1,ISYMBL)
ISN 0068            CALL SYMBOL(2.5,Y,0.10,ISYMBL,0.0,-1)
ISN 0069            CALL SYMBOL(3.4,Y,0.10,SAM,0.0,12)
ISN 0070            Y=Y-0.2
ISN 0071            RETURN
ISN 0072        100 CONTINUE
ISN 0073            CALL SYMBOL(2.0,Y1,0.10,21HAVE FAILURE STRESS = ,0.0,21)
ISN 0074            CALL NUMBER(4.1,Y1,0.10,XBAR1,0.0,2)
ISN 0075            CALL SYMBOL(2.0,Y2,0.10,21HAVE FAILURE STRAIN = ,0.0,21)
ISN 0076            CALL NUMBER(4.1,Y2,0.10,XBAR2,0.0,5)
ISN 0077            IX=IX+1
ISN 0078            IF (IX .EQ. 2) GO TO 10
ISN 0080            CALL PLOT(-2.5,8.5,-3)
ISN 0081            RETURN
ISN 0082         10 CALL PLOT(6.0,-13.5,-3)
ISN 0083            IX=0
ISN 0084            RETURN
ISN 0085            END

***** END OF COMPILATION ******
```

COMPUTER ANALYSIS WITH STIFFNESS-STRAIN PLOT.


```
ISN 0002             DIMENSION TITLE(20),DATE(5),TIME(20),LOAD(20),STRAIN(22),STRESS(22
                    1),FLSTRS(20),FLSTRN(20),FLTIME(20),SAMPLE(20,3),STIFF(20),FLSTFF(2
                    20),ORSTRS(20),ORSTRN(20),ORSTFF(20),ORTIME(20),UNITWT(20),BUF(2048
                    3),TITLE1(10),TITLE2(10),SAM(3),PLRESS(23),PLRAIN(23)
ISN 0003             INTEGER TIME,SAMPLE,FAILTM,TEMP
ISN 0004             REAL LOAD,MAXSTR,MAXSTF
ISN 0005             CALL PLOTS(BUF,8192)
ISN 0006             IX=0
ISN 0007             III=0
               C
               C
               C           M = THE NUMBER OF SETS OF SAMPLES TO BE PROCESSED DURING
               C               THIS RUN .
               C
               C
ISN 0008             READ(5,10)M
ISN 0009          10 FORMAT(I5)
ISN 0010             DO 300 II=1,M
               C
               C
               C       TITLE = A DESCRIPTION (80 COLUMNS OR LESS) TO APPEAR AT THE
               C               TOP OF EACH PAGE TO IDENTIFY EACH PARTICULAR SET .
               C
               C
ISN 0011             READ(5,20)(TITLE(K),K=1,20)
ISN 0012          20 FORMAT(20A4)
               C
               C
               C        TEMP = THE TEST TEMPERATURE , IN DEGREES FAHRENHEIT , AT
               C               WHICH THIS SET WAS RUN .
               C
               C        RATE = THE RATE OF LOAD APPLICATION IN INCHES PER MINUTE .
               C
               C        DATE = THE DATE AT WHICH THE SAMPLES WITHIN THIS SET
               C               WERE TESTED .
               C
               C
ISN 0013             READ(5,30)TEMP,RATE,(DATE(K),K=1,5)
ISN 0014          30 FORMAT(7X,I3,F10.3,5A4)
               C
               C
               C      MAXSTR = THE MAXIMUM STRAIN , IN TEN THOUSANDTHS OF AN INCH ,
               C               TO BE EXPECTED WITHIN THIS RUN . THIS IS REQUIRED TO
               C               ESTABLISH THE CORRECT SCALE FOR STRAIN ON THE CALCOMP
               C               PLOTTER . THIS MAY BE ANY VALUE , BUT THE FOLLOWING
               C               VALUES WILL PRODUCE CONVENIENT SCALES .
               C
               C
               C               MAXSTR                          SCALE
               C
               C                  10        1" =  2 TEN THOUSANDS OF AN INCH / INCH
               C                  25        1" =  5 TEN THOUSANDS OF AN INCH / INCH
               C                  50        1" = 10 TEN THOUSANDS OF AN INCH / INCH
               C                 100        1" = 20 TEN THOUSANDS OF AN INCH / INCH
               C
               C
ISN 0015             READ(5,35)MAXSTR
```

```
ISN 0016       35 FORMAT(F10.0)
            C
            C
            C          MAXSTF = THE MAXIMUM STIFFNESS OF MIX , IN PSI , TO BE EXPECTED
            C                   WITHIN THIS RUN . THIS IS REQUIRED TO ESTABLISH A
            C                   CONVENIENT SCALE FOR STIFFNESS ON THE CALCOMP
            C                   PLOTTER . THE VALUE CHOSEN SHOULD BE DIVISABLE BY 7
            C                   SINCE THE PRE-DETERMINED LENGTH OF THE Y-AXIS IS
            C                   EQUAL TO 7 INCHES . THE FOLLOWING VALUES WILL PRODUCE
            C                   CONVENIENT SCALES ( NOTE: IF THE MAXIMJM STIFFNESS IS
            C                   NOT KNOWN THE BEST PROCEDURE TO FOLLOW IS TO CHOSE A
            C                   VERY LARGE VALUE TO ENSURE THAT ALL STIFFNESS VALUES
            C                   WILL FALL WITHIN THE LIMITS OF THE PLOT ) .
            C
            C
            C                   MAXSTF              SCALE
            C
            C                    700000       1" =  100000 PSI
            C                   1400000       1" =  200000 PSI
            C                   2100000       1" =  300000 PSI
            C                   2800000       1" =  400000 PSI
            C                   3500000       1" =  500000 PSI
            C
            C                               ETC
            C
            C                   7000000       1" = 1000000 PSI
            C
            C
ISN 0017          READ(5,36) MAXSTF
ISN 0018       36 FORMAT(F10.0)
            C
            C
            C               N = THE NUMBER OF SAMPLES WITHIN THIS SET .
            C
            C
ISN 0019          READ(5,40)N
ISN 0020       40 FORMAT(I5)
ISN 0021          DO 200 I=1,N
            C
            C
            C          SAMPLE = THE IDENTIFICATION NUMBER OF THE SAMPLE .
            C
            C           WTAIR = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN AIR .
            C
            C           WTWAT = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN WATER .
            C
            C            DIAM = THE AVERAGE DIAMETER OF THE SAMPLE , IN INCHES .
            C
            C           THICK = THE AVERAGE THICKNESS OF THE SAMPLE , IN INCHES .
            C
            C               L = THE NUMBER OF LOAD AND STRAIN POINTS PICKED OFF THE
            C                   LOAD AND DEFORMATION STRIP CHART .
            C
            C          FAILTM = THE TIME TO FAILURE , IN SECONDS .
            C
            C
ISN 0022          READ(5,50)(SAMPLE(I,K),K=1,3),WTAIR,WTWAT,DIAM,THICK,L,FAILTM
```

```
ISN 0023        50 FORMAT(3A4,F8.3,3F10.3,2I10)
           C
           C
           C          SPGR = BULK SPECIFIC GRAVITY OF THE COMPACTED MIXTURE .
           C
           C
ISN 0024           SPGR=WTAIR/(WTAIR-WTWAT)
           C
           C
           C        UNITWT = UNIT WEIGHT OF THE COMPACTED MIXTURE ,
           C                 IN POUNDS PER CUBIC FOOT .
           C
           C
ISN 0025           UNITWT(I)=SPGR*62.4
ISN 0026           LN=N+1
ISN 0027           NN=N+2
ISN 0028           WRITE(6,60)(TITLE(K),K=1,20),I,NN,(SAMPLE(I,K),K=1,3),SPGR,UNITWT(
                  1I),DIAM,THICK
ISN 0029        60 FORMAT(1H1//////20X,20A4//91X,      5HPAGE ,I2,4H OF ,I2///44X,17H
                  1SAMPLE NUMBER :  ,3A4//32X,     49HBULK SPECIFIC GRAVITY OF THE COM
                  2PACTED MIXTURE = ,     F5.3//38X,14HUNIT WEIGHT = ,F5.1,22H POUNDS
                  2 PER CUBIC FOOT ,            //45X,11HDIAMETER = ,   F5.3,7H INCHES/
                  3/44X,12HTHICKNESS = ,      F5.3,7H INCHES//)
ISN 0030           WRITE(6,61) RATE,FAILTM,TEMP,(DATE(K),K=1,5)
ISN 0031        61 FORMAT(25X,15HDETAILS OF TEST//26X,18HRATE OF LOADING = ,F5.3,16H
                  1INCHES / MINUTE,4X,19HTIME TO FRACTURE = ,I3,8H SECONDS//26X,19HTE
                  2ST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,9HDATE :    ,5A4///)
ISN 0032           WRITE(6,62)
ISN 0033        62 FORMAT(60X,9HSTIFFNESS/30X,6HSTRESS,9X,6HSTRAIN,11X,6HOF MIX,10X,
                  14HTIME/31X,5H(PSI),9X,7H(IN/IN),10X,5H(PSI),9X,9H(SECONDS)///)
ISN 0034           DENOM=3.14159*DIAM*THICK
           C
           C
           C          TIME = THE TIME , IN SECONDS , FROM ZERO TIME TO EACH OF THE
           C                 POINTS ON THE LOAD AND DEFORMATION STRIP CHART .
           C
           C
ISN 0035           READ(5,70)(TIME(K),K=1,L)
ISN 0036        70 FORMAT(5X,15I5)
           C
           C
           C          LOAD = THE LOAD , IN POUNDS , AT EACH OF THE POINTS ON THE
           C                 LOAD TRACE .
           C
           C
ISN 0037           READ(5,80)(LOAD(K),K=1,L)
ISN 0038        80 FORMAT(5X,15F5.0)
           C
           C
           C        STRAIN = THE STRAIN , IN TEN THOUSANDTHS OF AN INCH / INCH ,
           C                 FOR EACH OF THE POINTS ON THE DEFORMATION TRACE .
           C
           C
ISN 0039           READ(5,90)(STRAIN(K),K=1,L)
ISN 0040        90 FORMAT(5X,15F5.0)
ISN 0041           DO 100 J=1,L
ISN 0042           STRESS(J)=2.*LOAD(J)/DENOM
```

```
ISN 0043          STRAIN(J)=STRAIN(J)*0.0001
           C
           C
           C         CONSIDERING AVERAGE TENSILE STRESS OVER A ONE INCH GAUGE LENGTH
           C         AND ASSUMING A POISSONS RATIO OF 0.33 .
           C
           C
ISN 0044          STIFF(J)=0.912*STRESS(J)/(STRAIN(J)*.5)
ISN 0045          ISTIFF=STIFF(J)
ISN 0046          WRITE(6,95)STRESS(J),STRAIN(J),ISTIFF,TIME(J)
ISN 0047       95 FORMAT(26X,F10.2,6X,F10.6,8X,I8,9X,I5/)
ISN 0048      100 CONTINUE
ISN 0049          FTEMP=TEMP
           C
           C
           C         SUBROUTINE 'GRAPH' IS CALLED SO THAT THE VALUES REQUIRED FOR
           C         THE CALCOMP PLOTTING OF STIFFNESS VERSUS STRAIN CAN BE STORED
           C         ON THE 7 TRACK PLOTTING TAPE .
           C
           C
ISN 0050          CALL GRAPH(BUF,STIFF ,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXSTR,N,II
                 1,III, XBAR3,XBAR2,MAXSTF)
           C
           C
           C         SUBROUTINE 'MAX' IS CALLED TO DETERMINE THE MAXIMUM SECANT
           C         MODULUS ( THAT IS THE MAXIMUM STIFFNESS OF MIX FOR EACH
           C         STRESS-STRAIN DIAGRAM ) .
           C
           C
ISN 0051          CALL MAX(L,STIFF,NNN)
ISN 0052          ORSTRS(I)=STRESS(NNN)
ISN 0053          ORSTRN(I)=STRAIN(NNN)
ISN 0054          ORSTFF(I)=STIFF(NNN)
ISN 0055          ORTIME(I)=TIME(NNN)
ISN 0056          FLSTRS(I)=STRESS(L)
ISN 0057          FLSTRN(I)=STRAIN(L)
ISN 0058          FLSTFF(I)=STIFF(L)
ISN 0059          FLTIME(I)=TIME(L)
ISN 0060      200 CONTINUE
           C
           C
           C         SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
           C         DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
           C         BASED UPON INITIAL CONDITIONS ( THAT IS THE MAXIMUM SECANT
           C         MODULUS OF EACH STRESS-STRAIN DIAGRAM ) .
           C
           C
ISN 0061          CALL STATS(N,ORSTRS,XBAR5,SIGMA5,VAR5)
ISN 0062          CALL STATS(N,ORSTRN,XBAR6,SIGMA6,VAR6)
ISN 0063          CALL STATS(N,ORSTFF,XBAR7,SIGMA7,VAR7)
ISN 0064          CALL STATS(N,ORTIME,XBAR8,SIGMA8,VAR8)
ISN 0065          CALL STATS(N,UNITWT,XBAR9,SIGMA9,VAR9)
ISN 0066          IXBAR7=XBAR7
ISN 0067          ISGMA7=SIGMA7
ISN 0068          WRITE(6,210)(TITLE(K),K=1,20),LN,NN,N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0069      210 FORMAT(1H1//////20X,20A4//91X,      5HPAGE ,I2,4H OF ,I2///29X,
                 159HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION/57X
```

```
                      2,3HFOR/44X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/44X,29HBASED UPON
                      3INITIAL CONDITIONS///15X,17HSAMPLE NUMBERS : ,3X,8(3A4))
ISN 0070               WRITE(6,211)TEMP,(DATE(K),K=1,5)
ISN 0071           211 FORMAT(//26X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,7
                      1HDATE : ,5A4)
ISN 0072               WRITE(6,212)
ISN 0073           212 FORMAT(////80X,9HSTIFFNESS,21X,4HUNIT/56X,6HSTRESS,6X,6HSTRAIN,8X,
                      16HOF MIX,8X,4HTIME,9X,6HWEIGHT/57X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI)
                      2,7X,9H(SECONDS),5X,8H(P.C.F.))
ISN 0074               WRITE(6,213) XBAR5,XBAR6,IXBAR7,XBAR8,XBAR9
ISN 0075           213 FORMAT(//23X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,3X,F10.1,7X,F7.2/)
ISN 0076               WRITE(6,214) SIGMA5,SIGMA6,ISGMA7,SIGMA8,SIGMA9
ISN 0077           214 FORMAT(23X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,3X,F10.1,
                      17X,F7.2/)
ISN 0078               WRITE(6,215) VAR5,VAR6,VAR7,VAR8,VAR9
ISN 0079           215 FORMAT(23X,28HCOEFFICIENT OF VARIATION (%),2X,F9.2,3X,F8.2,7X,F8.2
                      1,3X,F10.2,7X,F7.2///)
              C
              C
              C          SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
              C          DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
              C          BASED UPON FAILURE CONDITIONS .
              C
              C
ISN 0080               CALL STATS(N,FLSTRS,XBAR1,SIGMA1,VAR1)
ISN 0081               CALL STATS(N,FLSTRN,XBAR2,SIGMA2,VAR2)
ISN 0082               CALL STATS(N,FLSTFF,XBAR3,SIGMA3,VAR3)
ISN 0083               CALL STATS(N,FLTIME,XBAR4,SIGMA4,VAR4)
ISN 0084               IXBAR3=XBAR3
ISN 0085               ISGMA3=SIGMA3
ISN 0086               III=III+1
ISN 0087               CALL GRAPH(BUF,STIFF ,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXSTR,N,II
                      1,III, XBAR3,XBAR2,MAXSTF)
ISN 0088               WRITE(6,250)(TITLE(K),K=1,20),NN,NN,N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0089           250 FORMAT(1H1//////20X,20A4//91X,      5HPAGE ,I2,4H OF ,I2///29X,
                      159HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION/57X
                      2,3HFOR/44X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/44X,29HBASED UPON
                      3FAILURE CONDITIONS///15X,17HSAMPLE NUMBERS : ,3X,8(3A4))
ISN 0090               WRITE(6,251)TEMP,(DATE(K),K=1,5)
ISN 0091           251 FORMAT(//26X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,7
                      1HDATE : ,5A4)
ISN 0092               WRITE(6,252)
ISN 0093           252 FORMAT(////80X,9HSTIFFNESS,21X,4HUNIT/56X,6HSTRESS,6X,6HSTRAIN,8X,
                      16HOF MIX,8X,4HTIME,9X,6HWEIGHT/57X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI)
                      2,7X,9H(SECONDS),5X,8H(P.C.F.))
ISN 0094               WRITE(6,253) XBAR1,XBAR2,IXBAR3,XBAR4,XBAR9
ISN 0095           253 FORMAT(//23X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,3X,F10.1,7X,F7.2/)
ISN 0096               WRITE(6,254) SIGMA1,SIGMA2,ISGMA3,SIGMA4,SIGMA9
ISN 0097           254 FORMAT(23X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,3X,F10.1,
                      17X,F7.2/)
ISN 0098               WRITE(6,255) VAR1,VAR2,VAR3,VAR4,VAR9
ISN 0099           255 FORMAT(23X,28HCOEFFICIENT OF VARIATION (%),2X,F9.2,3X,F8.2,7X,F8.2
                      1,3X,F10.2,7X,F7.2///)
ISN 0100           300 CONTINUE
ISN 0101               CALL PLOT(0.0,0.0,999)
ISN 0102               WRITE(6,310)
ISN 0103           310 FORMAT(1H1)
```

```
  ISN 0104              STOP
  ISN 0105              END
ADCONS FOR EXTERNAL REFERENCES

****** END OF COMPILATION ******
```

```
  ISN 0002              SUBROUTINE MAX(L,ARRAY,NNN)
  ISN 0003              DIMENSION ARRAY(50)
  ISN 0004              AMAX=ARRAY(1)
  ISN 0005              NNN=1
  ISN 0006              DO 20 I=2,L
  ISN 0007              IF(ARRAY(I) .GT. AMAX) GO TO 10
  ISN 0009              GO TO 20
  ISN 0010           10 NNN=I
  ISN 0011              AMAX=ARRAY(I)
  ISN 0012           20 CONTINUE
  ISN 0013              RETURN
  ISN 0014              END

****** END OF COMPILATION ******
```

```
  ISN 0002              SUBROUTINE STATS(N,X,XBAR,SIGMA,VAR)
  ISN 0003              DIMENSION X(50)
  ISN 0004              SUM=0.
  ISN 0005              DO 10 I=1,N
  ISN 0006              SUM=SUM+X(I)
  ISN 0007           10 CONTINUE
  ISN 0008              AN=N
  ISN 0009              BN=N-1
  ISN 0010              XBAR=SUM/AN
  ISN 0011              SMSQDF=0.
  ISN 0012              DO 20 I=1,N
  ISN 0013              SMSQDF=SMSQDF+(X(I)-XBAR)**2
  ISN 0014           20 CONTINUE
  ISN 0015              SIGMA=(SMSQDF/BN)**0.5
  ISN 0016              VAR=SIGMA/XBAR*100.
  ISN 0017              RETURN
  ISN 0018              END

****** END OF COMPILATION ******
```

```
ISN 0002          SUBROUTINE GRAPH(BUF,STIFF ,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXST
                 1R,N,II,III, XBAR3,XBAR2,MAXSTF)
ISN 0003          DIMENSION  STIFF(22),STRAIN(22),TITLE(20),SAMPLE(20,3),TITLE1(10),
                 1TITLE2(10),SAM(3)
ISN 0004          REAL MAXSTR,MAXSTF
ISN 0005          STIFF(L+1)=0.0
ISN 0006          STRAIN(L+1)=0.0
ISN 0007          STIFF(L+2)=MAXSTF/7.0
ISN 0008          STRAIN(L+2)=MAXSTR*0.0001/5.0
ISN 0009          IF(I .GT. 1) GO TO 50
ISN 0011          CALL RECT(0.0,0.0,11.0,8.5,0.0,3)
ISN 0012          CALL PLOT(2.5,2.5,-3)
ISN 0013          CALL AXIS(0.0,0.0,'STRAIN , IN/IN',-14,5.0,0.0,STRAIN(L+1),STRAIN(
                 1L+2),10.0)
ISN 0014          CALL AXIS(0.0,0.0,'STIFFNESS OF MIX , PSI',22,7.0,90.0,STIFF(L+1),
                 1STIFF(L+2),20.0)
ISN 0015          CALL PLOT(5.0,0.0,3)
ISN 0016          CALL PLOT(5.0,7.0,2)
ISN 0017          CALL PLOT(0.0,7.0,2)
ISN 0018          X=0.0
ISN 0019          DO 1 J=1,6
ISN 0020          CALL SYMBOL(X,7.0,0.10,13,0.0,-1)
ISN 0021          X=X+1.0
ISN 0022        1 CONTINUE
ISN 0023          Y=0.0
ISN 0024          DO 2 J=1,15
ISN 0025          CALL SYMBOL(5.0,Y,0.10,13,90.0,-1)
ISN 0026          Y=Y+0.5
ISN 0027        2 CONTINUE
ISN 0028          DO 3 J=1,10
ISN 0029          TITLE1(J)=TITLE(J)
ISN 0030        3 CONTINUE
ISN 0031          K=0
ISN 0032          DO 5 J=11,20
ISN 0033          K=K+1
ISN 0034          TITLE2(K)=TITLE(J)
ISN 0035        5 CONTINUE
ISN 0036          CALL SYMBOL(0.5,6.8,0.12,TITLE1,0.0,40)
ISN 0037          CALL SYMBOL(0.5,6.6,0.12,TITLE2,0.0,40)
ISN 0038          CALL SYMBOL(1.5,6.4,0.10,19HTEST TEMPERATURE : ,0.0,19)
ISN 0039          CALL NUMBER(3.4,6.4,0.10,FTEMP,0.0,-1)
ISN 0040          CALL SYMBOL(3.7,6.4,0.10,1HF,0.0,1)
ISN 0041          CALL SYMBOL(2.9,5.5,0.12,6HLEGEND,0.0,6)
ISN 0042          CALL SYMBOL(2.2,5.25,0.10,24HSYMBOL      SAMPLE NUMBER,0.0,24)
ISN 0043          Y=5.0
ISN 0044       50 CONTINUE
ISN 0045          IF(II .EQ. III) GO TO 100
ISN 0047          DO 7 J=1,3
ISN 0048          SAM(J)=SAMPLE(I,J)
ISN 0049        7 CONTINUE
ISN 0050          ISYMBL=I+127
ISN 0051          CALL LINE(STRAIN,STIFF,L,1,1,ISYMBL)
ISN 0052          CALL SYMBOL(2.5,Y,0.10,ISYMBL,0.0,-1)
ISN 0053          CALL SYMBOL(3.4,Y,0.10,SAM,0.0,12)
ISN 0054          Y=Y-0.2
```

```
ISN 0055            RETURN
ISN 0056        100 CONTINUE
ISN 0057            CALL SYMBOL(1.7,6.0,0.10,24HAVE FAILURE STIFFNESS = ,0.0,24)
ISN 0058            CALL NUMBER(4.1,6.0,0.10,XBAR3,0.0,-1)
ISN 0059            CALL SYMBOL(2.0,5.8,0.10,21HAVE FAILURE STRAIN = ,0.0,21)
ISN 0060            CALL NUMBER(4.1,5.8,0.10,XBAR2,0.0,5)
ISN 0061            IF(II/2*2 .EQ. II) GO TO 121
ISN 0063            CALL PLOT(-10.0,-12.0,-3)
ISN 0064            GO TO 122
ISN 0065        121 CALL PLOT(8.0,-3.0,-3)
ISN 0066        122 CONTINUE
ISN 0067            RETURN
ISN 0068            END

****** END OF COMPILATION ******
```

COMPUTER ANALYSIS WITH STRESS-STRAIN AND STIFFNESS-STRAIN PLOTS

```
ISN 0002          DIMENSION TITLE(20),DATE(5),TIME(20),LOAD(20),STRAIN(22),STRESS(22
                 1),FLSTRS(20),FLSTRN(20),FLTIME(20),SAMPLE(20,3),STIFF(20),FLSTFF(2
                 20),ORSTRS(20),ORSTRN(20),ORSTFF(20),ORTIME(20),UNITWT(20),BUF(2048
                 3),TITLE1(10),TITLE2(10),SAM(3)
ISN 0003          INTEGER TIME,SAMPLE,FAILTM,TEMP
ISN 0004          REAL LOAD,MAXSTR,MAXSTF
ISN 0005          CALL PLOTS(BUF,8192)
ISN 0006          IX=0
ISN 0007          III=0
            C
            C
            C              M = THE NUMBER OF SETS OF SAMPLES TO BE PROCESSED DURING
            C                      THIS RUN .
            C
            C
ISN 0008          READ(5,10)M
ISN 0009       10 FORMAT(I5)
ISN 0010          DO 300 II=1,M
            C
            C
            C          TITLE = A DESCRIPTION (80 COLUMNS OR LESS) TO APPEAR AT THE
            C                  TOP OF EACH PAGE TO IDENTIFY EACH PARTICULAR SET .
            C
            C
ISN 0011          READ(5,20)(TITLE(K),K=1,20)
ISN 0012       20 FORMAT(20A4)
            C
            C
            C           TEMP = THE TEST TEMPERATURE , IN DEGREES FAHRENHEIT , AT
            C                  WHICH THIS SET WAS RUN .
            C
            C           RATE = THE RATE OF LOAD APPLICATION IN INCHES PER MINUTE .
            C
            C           DATE = THE DATE AT WHICH THE SAMPLES WITHIN THIS SET
            C                  WERE TESTED .
            C
            C
ISN 0013          READ(5,30)TEMP,RATE,(DATE(K),K=1,5)
ISN 0014       30 FORMAT(7X,I3,F10.3,5A4)
            C
            C
            C         MAXSTR = THE MAXIMUM STRAIN , IN TEN THOUSANDTHS OF AN INCH ,
            C                  TO BE EXPECTED WITHIN THIS RUN . THIS IS REQUIRED TO
            C                  ESTABLISH THE CORRECT SCALE FOR STRAIN ON THE CALCOMP
            C                  PLOTTER . THIS MAY BE ANY VALUE , BUT THE FOLLOWING
            C                  VALUES WILL PRODUCE CONVENIENT SCALES .
            C
            C
            C                  MAXSTR                        SCALE
            C
            C                     10      1" =  2 TEN THOUSANDS OF AN INCH / INCH
            C                     25      1" =  5 TEN THOUSANDS OF AN INCH / INCH
            C                     50      1" = 10 TEN THOUSANDS OF AN INCH / INCH
            C                    100      1" = 20 TEN THOUSANDS OF AN INCH / INCH
            C
            C
ISN 0015          READ(5,35)MAXSTR
```

```
ISN 0016        35 FORMAT(F10.0)
          C
          C
          C         MAXSTF = THE MAXIMUM STIFFNESS OF MIX , IN PSI , TO BE EXPECTED
          C                  WITHIN THIS RUN . THIS IS REQUIRED TO ESTABLISH A
          C                  CONVENIENT SCALE FOR STIFFNESS ON THE CALCOMP
          C                  PLOTTER . THE VALUE CHOSEN SHOULD BE DIVISABLE BY 7
          C                  SINCE THE PRE-DETERMINED LENGTH OF THE Y-AXIS IS
          C                  EQUAL TO 7 INCHES . THE FOLLOWING VALUES WILL PRODUCE
          C                  CONVENIENT SCALES ( NOTE: IF THE MAXIMUM STIFFNESS IS
          C                  NOT KNOWN THE BEST PROCEDURE TO FOLLOW IS TO CHOSE A
          C                  VERY LARGE VALUE TO ENSURE THAT ALL STIFFNESS VALUES
          C                  WILL FALL WITHIN THE LIMITS OF THE PLOT ) .
          C
          C
          C                  MAXSTF              SCALE
          C
          C                   700000       1" =  100000 PSI
          C                  1400000       1" =  200000 PSI
          C                  2100000       1" =  300000 PSI
          C                  2800000       1" =  400000 PSI
          C                  3500000       1" =  500000 PSI
          C
          C                                ETC
          C
          C                  7000000       1" = 1000000 PSI
          C
          C
ISN 0017           READ(5,36) MAXSTF
ISN 0018        36 FORMAT(F10.0)
          C
          C
          C              N = THE NUMBER OF SAMPLES WITHIN THIS SET .
          C
          C
ISN 0019           READ(5,40)N
ISN 0020        40 FORMAT(I5)
ISN 0021           DO 200 I=1,N
          C
          C
          C         SAMPLE = THE IDENTIFICATION NUMBER OF THE SAMPLE .
          C
          C          WTAIR = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN AIR .
          C
          C          WTWAT = THE WEIGHT , IN GRAMS , OF THE SAMPLE IN WATER .
          C
          C           DIAM = THE AVERAGE DIAMETER OF THE SAMPLE , IN INCHES .
          C
          C          THICK = THE AVERAGE THICKNESS OF THE SAMPLE , IN INCHES .
          C
          C              L = THE NUMBER OF LOAD AND STRAIN POINTS PICKED OFF THE
          C                  LOAD AND DEFORMATION STRIP CHART .
          C
          C         FAILTM = THE TIME TO FAILURE , IN SECONDS .
          C
          C
ISN 0022           READ(5,50)(SAMPLE(I,K),K=1,3),WTAIR,WTWAT,DIAM,THICK,L,FAILTM
```

```
ISN 0023          50 FORMAT(3A4,F8.3,3F10.3,2I10)
              C
              C
              C          SPGR = BULK SPECIFIC GRAVITY OF THE COMPACTED MIXTURE .
              C
              C
ISN 0024             SPGR=WTAIR/(WTAIR-WTWAT)
              C
              C
              C        UNITWT = UNIT WEIGHT OF THE COMPACTED MIXTURE ,
              C                 IN POUNDS PER CUBIC FOOT .
              C
              C
ISN 0025             UNITWT(I)=SPGR*62.4
ISN 0026             LN=N+1
ISN 0027             NN=N+2
ISN 0028             WRITE(6,60)(TITLE(K),K=1,20),I,NN,(SAMPLE(I,K),K=1,3),SPGR,UNITWT(
                    1I),DIAM,THICK
ISN 0029          60 FORMAT(1H1//////20X,20A4//91X,       5HPAGE ,I2,4H OF ,I2///44X,17H
                    1SAMPLE NUMBER :  ,3A4//32X,     49HBULK SPECIFIC GRAVITY OF THE COM
                    2PACTED MIXTURE = ,        F5.3//38X,14HUNIT WEIGHT = ,F5.1,22H POUNDS
                    2 PER CUBIC FOOT ,              //45X,11HDIAMETER = ,    F5.3,7H INCHES/
                    3/44X,12HTHICKNESS = ,      F5.3,7H INCHES//)
ISN 0030             WRITE(6,61) RATE,FAILTM,TEMP,(DATE(K),K=1,5)
ISN 0031          61 FORMAT(25X,15HDETAILS OF TEST//26X,18HRATE OF LOADING = ,F5.3,16H
                    1INCHES / MINUTE,4X,19HTIME TO FRACTURE = ,I3,8H SECONDS//26X,19HTE
                    2ST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,9HDATE :    ,5A4///)
ISN 0032             WRITE(6,62)
ISN 0033          62 FORMAT(60X,9HSTIFFNESS/30X,6HSTRESS,9X,6HSTRAIN,11X,6HOF MIX,10X,
                    14HTIME/31X,5H(PSI),9X,7H(IN/IN),10X,5H(PSI),9X,9H(SECONDS)///)
ISN 0034             DENOM=3.14159*DIAM*THICK
              C
              C
              C          TIME = THE TIME , IN SECONDS , FROM ZERO TIME TO EACH OF THE
              C                 POINTS ON THE LOAD AND DEFORMATION STRIP CHART .
              C
              C
ISN 0035             READ(5,70)(TIME(K),K=1,L)
ISN 0036          70 FORMAT(5X,15I5)
              C
              C
              C          LOAD = THE LOAD , IN POUNDS , AT EACH OF THE POINTS ON THE
              C                 LOAD TRACE .
              C
              C
ISN 0037             READ(5,80)(LOAD(K),K=1,L)
ISN 0038          80 FORMAT(5X,15F5.0)
              C
              C
              C        STRAIN = THE STRAIN , IN TEN THOUSANDTHS OF AN INCH / INCH ,
              C                 FOR EACH OF THE POINTS ON THE DEFORMATION TRACE .
              C
              C
              C
ISN 0039             READ(5,90)(STRAIN(K),K=1,L)
ISN 0040          90 FORMAT(5X,15F5.0)
ISN 0041             DO 100 J=1,L
ISN 0042             STRESS(J)=2.*LOAD(J)/DENOM
```

```
ISN 0043          STRAIN(J)=STRAIN(J)*0.0001
            C
            C
            C         CONSIDERING AVERAGE TENSILE STRESS OVER A ONE INCH GAUGE LENGTH
            C         AND ASSUMING A POISSONS RATIO OF 0.33 .
            C
            C
ISN 0044          STIFF(J)=0.912*STRESS(J)/(STRAIN(J)*.5)
ISN 0045          ISTIFF=STIFF(J)
ISN 0046          WRITE(6,95)STRESS(J),STRAIN(J),ISTIFF,TIME(J)
ISN 0047       95 FORMAT(26X,F10.2,6X,F10.6,8X,I8,9X,I5/)
ISN 0048      100 CONTINUE
ISN 0049          FTEMP=TEMP
            C
            C
            C         SUBROUTINE 'GRAPH1' IS CALLED SO THAT VALUES REQUIRED FOR
            C         THE CALCOMP PLOTTING OF STRESS VERSUS STRAIN CAN BE STORED
            C         ON THE 7 TRACK PLOTTING TAPE .
            C
            C
ISN 0050          CALL GRAPH1(BUF,STRESS,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXSTR,N,I
                 1I,III,XBAR1,XBAR2)
            C
            C
            C         SUBROUTINE 'GRAPH2' IS CALLED SO THAT VALUES REQUIRED FOR
            C         THE CALCOMP PLOTTING OF STIFFNESS VERSUS STRAIN CAN BE STORED
            C         ON THE 7 TRACK PLOTTING TAPE .
            C
            C
ISN 0051          CALL GRAPH2(BUF,STIFF,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXSTR,N,II
                 1,III, XBAR3,XBAR2,MAXSTF)
            C
            C
            C         SUBROUTINE 'MAX' IS CALLED TO DETERMINE THE MAXIMUM SECANT
            C         MODULUS ( THAT IS THE MAXIMUM STIFFNESS OF MIX FOR EACH
            C         STRESS-STRAIN DIAGRAM ) .
            C
            C
ISN 0052          CALL MAX(L,STIFF,NNN)
ISN 0053          ORSTRS(I)=STRESS(NNN)
ISN 0054          ORSTRN(I)=STRAIN(NNN)
ISN 0055          ORSTFF(I)=STIFF(NNN)
ISN 0056          ORTIME(I)=TIME(NNN)
ISN 0057          FLSTRS(I)=STRESS(L)
ISN 0058          FLSTRN(I)=STRAIN(L)
ISN 0059          FLSTFF(I)=STIFF(L)
ISN 0060          FLTIME(I)=TIME(L)
ISN 0061      200 CONTINUE
            C
            C
            C         SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
            C         DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
            C         BASED UPON INITIAL CONDITIONS ( THAT IS THE MAXIMUM SECANT
            C         MODULUS OF EACH STRESS-STRAIN DIAGRAM ) .
            C
            C
ISN 0062          CALL STATS(N,ORSTRS,XBAR5,SIGMA5,VAR5)
```

```
ISN 0063          CALL STATS(N,ORSTRN,XBAR6,SIGMA6,VAR6)
ISN 0064          CALL STATS(N,ORSTFF,XBAR7,SIGMA7,VAR7)
ISN 0065          CALL STATS(N,ORTIME,XBAR8,SIGMA8,VAR8)
ISN 0066          CALL STATS(N,UNITWT,XBAR9,SIGMA9,VAR9)
ISN 0067          IXBAR7=XBAR7
ISN 0068          ISGMA7=SIGMA7
ISN 0069          WRITE(6,210)(TITLE(K),K=1,20),LN,NN,N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0070      210 FORMAT(1H1//////20X,20A4//91X,       5HPAGE ,I2,4H OF ,I2///29X,
                 159HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION/57X
                 2,3HFOR/44X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/44X,29HBASED UPON
                 3INITIAL CONDITIONS///15X,17HSAMPLE NUMBERS : ,3X,8(3A4))
ISN 0071          WRITE(6,211)TEMP,(DATE(K),K=1,5)
ISN 0072      211 FORMAT(//26X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,7
                 1HDATE : ,5A4)
ISN 0073          WRITE(6,212)
ISN 0074      212 FORMAT(////80X,9HSTIFFNESS,21X,4HUNIT/56X,6HSTRESS,6X,6HSTRAIN,8X,
                 16HOF MIX,8X,4HTIME,9X,6HWEIGHT/57X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI)
                 2,7X,9H(SECONDS),5X,8H(P.C.F.))
ISN 0075          WRITE(6,213) XBAR5,XBAR6,IXBAR7,XBAR8,XBAR9
ISN 0076      213 FORMAT(//23X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,3X,F10.1,7X,F7.2/)
ISN 0077          WRITE(6,214) SIGMA5,SIGMA6,ISGMA7,SIGMA8,SIGMA9
ISN 0078      214 FORMAT(23X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,3X,F10.1,
                 17X,F7.2/)
ISN 0079          WRITE(6,215) VAR5,VAR6,VAR7,VAR8,VAR9
ISN 0080      215 FORMAT(23X,28HCOEFFICIENT OF VARIATION (%),2X,F9.2,3X,F8.2,7X,F8.2
                 1,3X,F10.2,7X,F7.2///)
            C
            C
            C        SUBROUTINE 'STATS' IS CALLED TO DETERMINE THE MEAN , STANDARD
            C        DEVIATION , AND COEFFICIENT OF VARIATION OF EACH PARAMETER
            C        BASED UPON FAILURE CONDITIONS .
            C
            C
ISN 0081          CALL STATS(N,FLSTRS,XBAR1,SIGMA1,VAR1)
ISN 0082          CALL STATS(N,FLSTRN,XBAR2,SIGMA2,VAR2)
ISN 0083          CALL STATS(N,FLSTFF,XBAR3,SIGMA3,VAR3)
ISN 0084          CALL STATS(N,FLTIME,XBAR4,SIGMA4,VAR4)
ISN 0085          IXBAR3=XBAR3
ISN 0086          ISGMA3=SIGMA3
ISN 0087          III=III+1
ISN 0088          CALL GRAPH1(BUF,STRESS,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXSTR,N,I
                 1I,III,XBAR1,XBAR2)
ISN 0089          CALL GRAPH2(BUF,STIFF,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXSTR,N,II
                 1,III, XBAR3,XBAR2,MAXSTF)
ISN 0090          WRITE(6,250)(TITLE(K),K=1,20),NN,NN,N,((SAMPLE(I,K),K=1,3),I=1,N)
ISN 0091      250 FORMAT(1H1//////20X,20A4//91X,       5HPAGE ,I2,4H OF ,I2///29X,
                 159HMEANS , STANDARD DEVIATIONS , AND COEFFICIENTS OF VARIATION/57X
                 2,3HFOR/44X,4HTHE ,I2,23H SAMPLES IN THIS SERIES/44X,29HBASED UPON
                 3FAILURE CONDITIONS///15X,17HSAMPLE NUMBERS : ,3X,8(3A4))
ISN 0092          WRITE(6,251)TEMP,(DATE(K),K=1,5)
ISN 0093      251 FORMAT(//26X,19HTEST TEMPERATURE : ,I3,19H DEGREES FAHRENHEIT,4X,7
                 1HDATE : ,5A4)
ISN 0094          WRITE(6,252)
ISN 0095      252 FORMAT(////80X,9HSTIFFNESS,21X,4HUNIT/56X,6HSTRESS,6X,6HSTRAIN,8X,
                 16HOF MIX,8X,4HTIME,9X,6HWEIGHT/57X,5H(PSI),6X,7H(IN/IN),7X,5H(PSI)
                 2,7X,9H(SECONDS),5X,8H(P.C.F.))
ISN 0096          WRITE(6,253) XBAR1,XBAR2,IXBAR3,XBAR4,XBAR9
```

```
 ISN 0097        253 FORMAT(//23X,4HMEAN,26X,F9.2,3X,F10.6,5X,I8,3X,F10.1,7X,F7.2/)
 ISN 0098            WRITE(6,254) SIGMA1,SIGMA2,ISGMA3,SIGMA4,SIGMA9
 ISN 0099        254 FORMAT(23X,18HSTANDARD DEVIATION,12X,F9.2,3X,F10.6,5X,I8,3X,F10.1,
                    17X,F7.2/)
 ISN 0100            WRITE(6,255) VAR1,VAR2,VAR3,VAR4,VAR9
 ISN 0101        255 FORMAT(23X,28HCOEFFICIENT OF VARIATION (%),2X,F9.2,3X,F8.2,7X,F8.2
                    1,3X,F10.2,7X,F7.2///)
 ISN 0102        300 CONTINUE
 ISN 0103            CALL PLOT(0.0,0.0,999)
 ISN 0104            WRITE(6,310)
 ISN 0105        310 FORMAT(1H1)
 ISN 0106            STOP
 ISN 0107            END
DCONS FOR EXTERNAL REFERENCES

***** END OF COMPILATION ******

 ISN 0002            SUBROUTINE MAX(L,ARRAY,NNN)
 ISN 0003            DIMENSION ARRAY(50)
 ISN 0004            AMAX=ARRAY(1)
 ISN 0005            NNN=1
 ISN 0006            DO 20 I=2,L
 ISN 0007            IF(ARRAY(I) .GT. AMAX) GO TO 10
 ISN 0009            GO TO 20
 ISN 0010         10 NNN=I
 ISN 0011            AMAX=ARRAY(I)
 ISN 0012         20 CONTINUE
 ISN 0013            RETURN
 ISN 0014            END

***** END OF COMPILATION ******

 ISN 0002            SUBROUTINE STATS(N,X,XBAR,SIGMA,VAR)
 ISN 0003            DIMENSION X(50)
 ISN 0004            SUM=0.
 ISN 0005            DO 10 I=1,N
 ISN 0006            SUM=SUM+X(I)
 ISN 0007         10 CONTINUE
 ISN 0008            AN=N
 ISN 0009            BN=N-1
 ISN 0010            XBAR=SUM/AN
 ISN 0011            SMSQDF=0.
 ISN 0012            DO 20 I=1,N
 ISN 0013            SMSQDF=SMSQDF+(X(I)-XBAR)**2
 ISN 0014         20 CONTINUE
 ISN 0015            SIGMA=(SMSQDF/BN)**0.5
 ISN 0016            VAR=SIGMA/XBAR*100.
 ISN 0017            RETURN
 ISN 0018            END

***** END OF COMPILATION ******
```

```
ISN 0002           SUBROUTINE GRAPH1(BUF,STRESS,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXS
                  1TR,N,II,III,XBAR1,XBAR2)
ISN 0003           DIMENSION STRESS(22),STRAIN(22),TITLE(20),SAMPLE(20,3),TITLE1(10),
                  1TITLE2(10),SAM(3),PLRESS(23),PLRAIN(23)
ISN 0004           REAL MAXSTR
ISN 0005           INTEGER U,V,W
ISN 0006           PLRESS(1)=0.0
ISN 0007           PLRAIN(1)=0.0
ISN 0008           U=L+1
ISN 0009           W=1
ISN 0010           DO 300 V=2,U
ISN 0011           PLRESS(V)=STRESS(W)
ISN 0012           PLRAIN(V)=STRAIN(W)
ISN 0013           W=W+1
ISN 0014       300 CONTINUE
ISN 0015           PLRESS(U+1)=0.0
ISN 0016           PLRAIN(U+1)=0.0
ISN 0017           PLRESS(U+2)=100.0
ISN 0018           PLRAIN(U+2)=MAXSTR*0.0001/5.0
ISN 0019           IF(I .GT. 1) GO TO 50
ISN 0021           IF(II/2*2 .EQ. II) GO TO 21
ISN 0023           CALL RECT(0.0,0.0,22.0,17.0,0.0,3)
ISN 0024           CALL PLOT(0.0,9.0,-3)
ISN 0025        21 CONTINUE
ISN 0026           CALL PLOT(3.0,3.0,-3)
ISN 0027           CALL AXIS(0.0,0.0,'STRAIN , IN/IN',-14,5.0,0.0,PLRAIN(U+1),PLRAIN(
                  1U+2),10.0)
ISN 0028           CALL AXIS(0.0,0.0,'TENSILE STRESS , PSI',20,7.0,90.0,PLRESS(U+1),P
                  1LRESS(U+2),20.0)
ISN 0029           CALL PLOT(5.0,0.0,3)
ISN 0030           CALL PLOT(5.0,7.0,2)
ISN 0031           CALL PLOT(0.0,7.0,2)
ISN 0032           X=0.0
ISN 0033           DO 1 J=1,6
ISN 0034           CALL SYMBOL(X,7.0,0.10,13,0.0,-1)
ISN 0035           X=X+1.0
ISN 0036         1 CONTINUE
ISN 0037           Y=0.0
ISN 0038           DO 2 J=1,15
ISN 0039           CALL SYMBOL(5.0,Y,0.10,13,90.0,-1)
ISN 0040           Y=Y+0.5
ISN 0041         2 CONTINUE
ISN 0042           DO 3 J=1,10
ISN 0043           TITLE1(J)=TITLE(J)
ISN 0044         3 CONTINUE
ISN 0045           K=0
ISN 0046           DO 5 J=11,20
ISN 0047           K=K+1
ISN 0048           TITLE2(K)=TITLE(J)
ISN 0049         5 CONTINUE
ISN 0050           CALL SYMBOL(0.5,6.8,0.12,TITLE1,0.0,40)
ISN 0051           CALL SYMBOL(0.5,6.6,0.12,TITLE2,0.0,40)
ISN 0052           CALL SYMBOL(1.5,6.4,0.10,19HTEST TEMPERATURE : ,0.0,19)
ISN 0053           CALL NUMBER(3.4,6.4,0.10,FTEMP,0.0,-1)
ISN 0054           CALL SYMBOL(3.7,6.4,0.10,1HF,0.0,1)
```

```
ISN 0055            IF (PLRESS(U) .GT. 400.) GO TO 30
ISN 0057            Y1=6.0
ISN 0058            Y2=5.8
ISN 0059            Y3=5.5
ISN 0060            Y4=5.25
ISN 0061            Y5=5.0
ISN 0062            GO TO 40
ISN 0063         30 CONTINUE
ISN 0064            AN=N
ISN 0065            Y1=AN*0.2+1.0
ISN 0066            Y2=Y1-0.2
ISN 0067            Y3=Y2-0.3
ISN 0068            Y4=Y3-0.25
ISN 0069            Y5=Y4-0.25
ISN 0070         40 CONTINUE
ISN 0071            CALL SYMBOL(2.9,Y3,0.12,6HLEGEND,0.0,6)
ISN 0072            CALL SYMBOL(2.2,Y4,0.10,24HSYMBOL      SAMPLE NUMBER,0.0,24)
ISN 0073            Y=Y5
ISN 0074         50 CONTINUE
ISN 0075            IF(II .EQ. III) GO TO 100
ISN 0077            DO 7 J=1,3
ISN 0078            SAM(J)=SAMPLE(I,J)
ISN 0079          7 CONTINUE
ISN 0080            ISYMBL=I+127
ISN 0081            CALL LINE(PLRAIN,PLRESS,U,1,1,ISYMBL)
ISN 0082            CALL SYMBOL(2.5,Y,0.10,ISYMBL,0.0,-1)
ISN 0083            CALL SYMBOL(3.4,Y,0.10,SAM,0.0,12)
ISN 0084            Y=Y-0.2
ISN 0085            RETURN
ISN 0086        100 CONTINUE
ISN 0087            CALL SYMBOL(2.0,Y1,0.10,21HAVE FAILURE STRESS = ,0.0,21)
ISN 0088            CALL NUMBER(4.1,Y1,0.10,XBAR1,0.0,2)
ISN 0089            CALL SYMBOL(2.0,Y2,0.10,21HAVE FAILURE STRAIN = ,0.0,21)
ISN 0090            CALL NUMBER(4.1,Y2,0.10,XBAR2,0.0,5)
ISN 0091            RETURN
ISN 0092            END

****** END OF COMPILATION ******
```

```
ISN 0002          SUBROUTINE GRAPH2(BUF,STIFF,STRAIN,L,IX,TITLE,SAMPLE,I,FTEMP,MAXST
                 1R,M,II,III, XBAR3,XBAR2,MAXSTF)
ISN 0003          DIMENSION  STIFF(22),STRAIN(22),TITLE(20),SAMPLE(20,3),TITLE1(10),
                 1TITLE2(10),SAM(3)
ISN 0004          REAL MAXSTR,MAXSTF
ISN 0005          STIFF(L+1)=0.0
ISN 0006          STRAIN(L+1)=0.0
ISN 0007          STIFF(L+2)=MAXSTF/7.0
ISN 0008          STRAIN(L+2)=MAXSTR*0.0001/5.0
ISN 0009          CALL PLOT(7.0,0.0,-3)
ISN 0010          IF(I .GT. 1) GO TO 50
ISN 0012          CALL AXIS(0.0,0.0,'STRAIN , IN/IN',-14,5.0,0.0,STRAIN(L+1),STRAIN(
                 1L+2),10.0)
ISN 0013          CALL AXIS(0.0,0.0,'STIFFNESS OF MIX , PSI',22,7.0,90.0,STIFF(L+1),
                 1STIFF(L+2),20.0)
ISN 0014          CALL PLOT(5.0,0.0,3)
ISN 0015          CALL PLOT(5.0,7.0,2)
ISN 0016          CALL PLOT(0.0,7.0,2)
ISN 0017          X=0.0
ISN 0018          DO 1 J=1,6
ISN 0019          CALL SYMBOL(X,7.0,0.10,13,0.0,-1)
ISN 0020          X=X+1.0
ISN 0021        1 CONTINUE
ISN 0022          Y=0.0
ISN 0023          DO 2 J=1,15
ISN 0024          CALL SYMBOL(5.0,Y,0.10,13,90.0,-1)
ISN 0025          Y=Y+0.5
ISN 0026        2 CONTINUE
ISN 0027          DO 3 J=1,10
ISN 0028          TITLE1(J)=TITLE(J)
ISN 0029        3 CONTINUE
ISN 0030          K=0
ISN 0031          DO 5 J=11,20
ISN 0032          K=K+1
ISN 0033          TITLE2(K)=TITLE(J)
ISN 0034        5 CONTINUE
ISN 0035          CALL SYMBOL(0.5,6.8,0.12,TITLE1,0.0,40)
ISN 0036          CALL SYMBOL(0.5,6.6,0.12,TITLE2,0.0,40)
ISN 0037          CALL SYMBOL(1.5,6.4,0.10,19HTEST TEMPERATURE : ,0.0,19)
ISN 0038          CALL NUMBER(3.4,6.4,0.10,FTEMP,0.0,-1)
ISN 0039          CALL SYMBOL(3.7,6.4,0.10,1HF,0.0,1)
ISN 0040          CALL SYMBOL(2.9,5.5,0.12,6HLEGEND,0.0,6)
ISN 0041          CALL SYMBOL(2.2,5.25,0.10,24HSYMBOL      SAMPLE NUMBER,0.0,24)
ISN 0042          Y=5.0
ISN 0043       50 CONTINUE
ISN 0044          IF(II .EQ. III) GO TO 100
ISN 0046          DO 7 J=1,3
ISN 0047          SAM(J)=SAMPLE(I,J)
ISN 0048        7 CONTINUE
ISN 0049          ISYMBL=I+127
ISN 0050          CALL LINE(STRAIN,STIFF,L,1,1,ISYMBL)
ISN 0051          CALL SYMBOL(2.5,Y,0.10,ISYMBL,0.0,-1)
ISN 0052          CALL SYMBOL(3.4,Y,0.10,SAM,0.0,12)
ISN 0053          Y=Y-0.2
ISN 0054          CALL PLOT(-7.0,0.0,-3)
```

```
 ISN 0055              RETURN
 ISN 0056          100 CONTINUE
 ISN 0057              CALL SYMBOL(1.7,6.0,0.10,24HAVE FAILURE STIFFNESS = ,0.0,24)
 ISN 0058              CALL NUMBER(4.1,6.0,0.10,XBAR3,0.0,-1)
 ISN 0059              CALL SYMBOL(2.0,5.8,0.10,21HAVE FAILURE STRAIN = ,0.0,21)
 ISN 0060              CALL NUMBER(4.1,5.8,0.10,XBAR2,0.0,5)
 ISN 0061              IX=IX+1
 ISN 0062              IF (IX .EQ. 2) GO TO 10
 ISN 0064              CALL PLOT(-2.5,8.5,-3)
 ISN 0065              RETURN
 ISN 0066           10 CALL PLOT(6.0,-13.5,-3)
 ISN 0067              IX=0
 ISN 0068              RETURN
 ISN 0069              END

***** END OF COMPILATION ******
```

A P P E N D I X B

COMPUTER PLOTS OF TENSILE STRESS VS. STRAIN
AND STIFFNESS OF MIX VS. STRAIN FOR
HIGHWAY 2-D-2/1 & 2/2 CORES
AT VARIOUS TEMPERATURES AND AGES

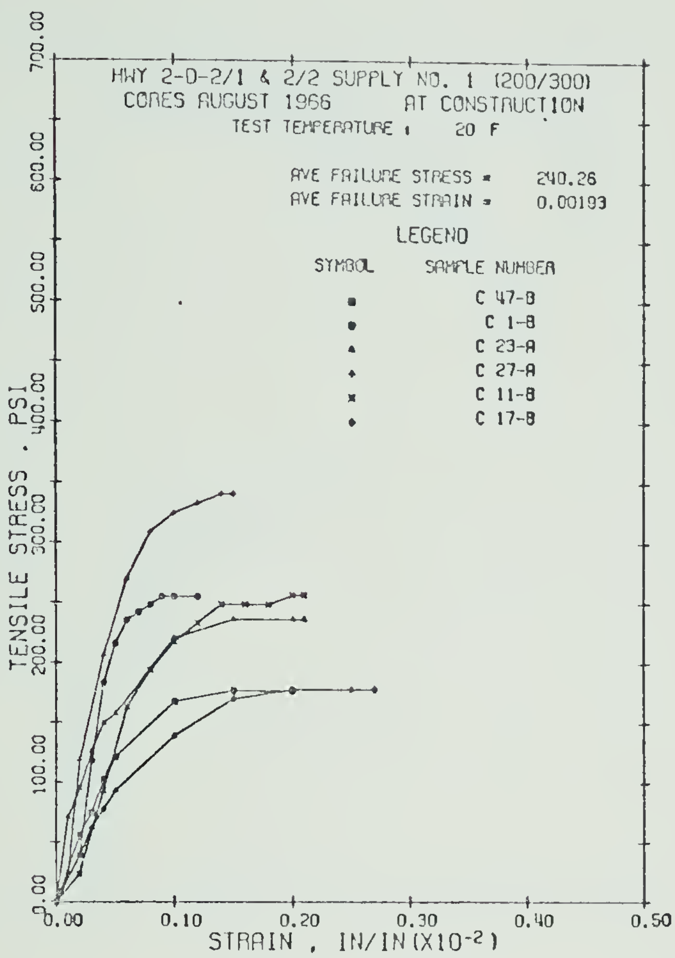


FIG. B1(a)

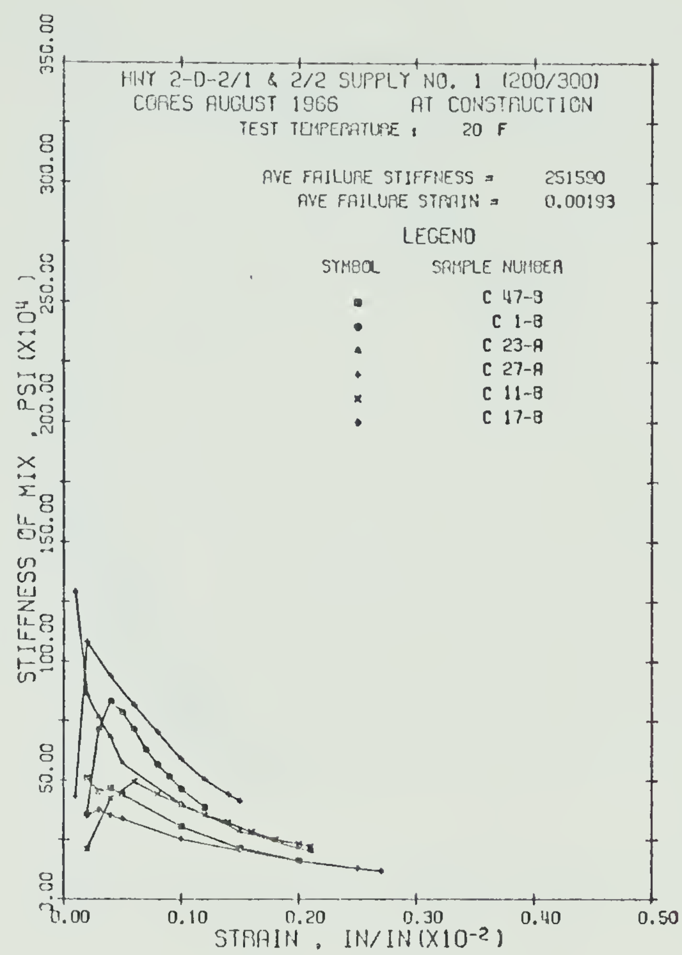


FIG. B1(b)

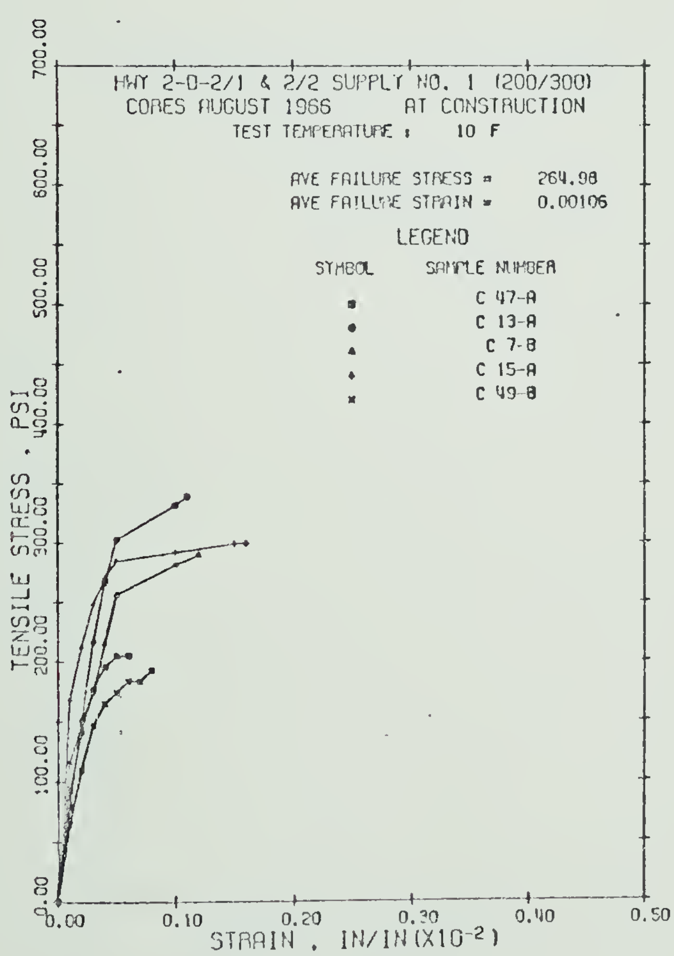


FIG. B1(c)

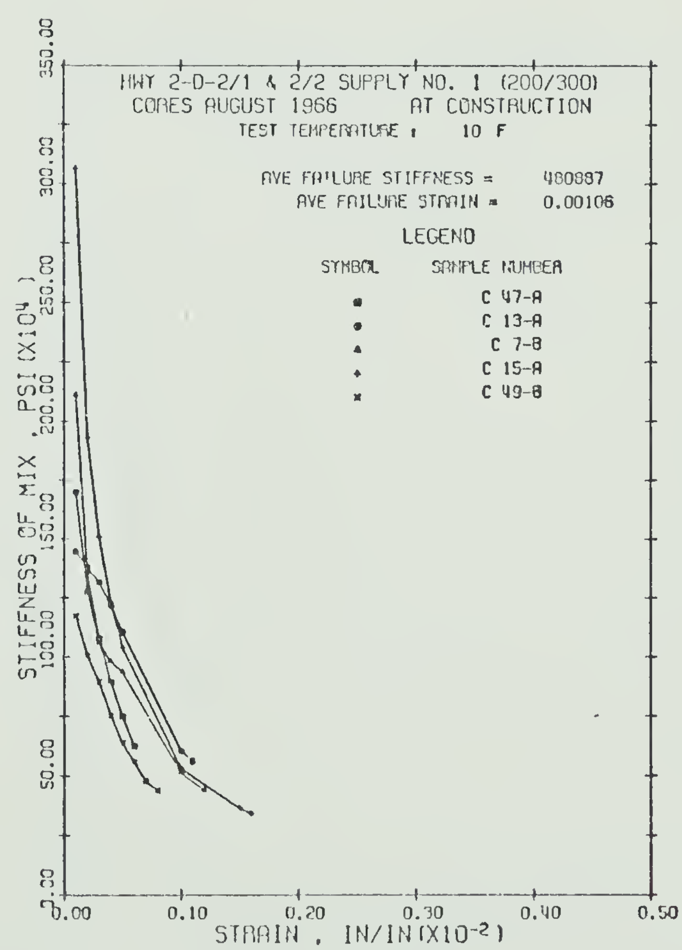


FIG. B1(d)

FIGURE B1: Supply No. 1 - At Construction

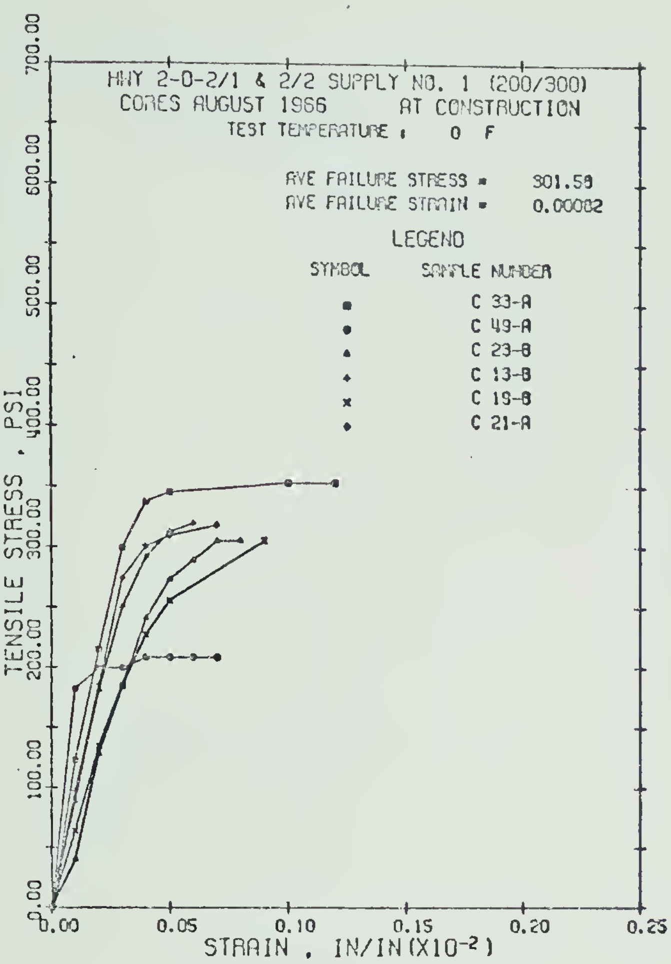


FIG. B2(a)

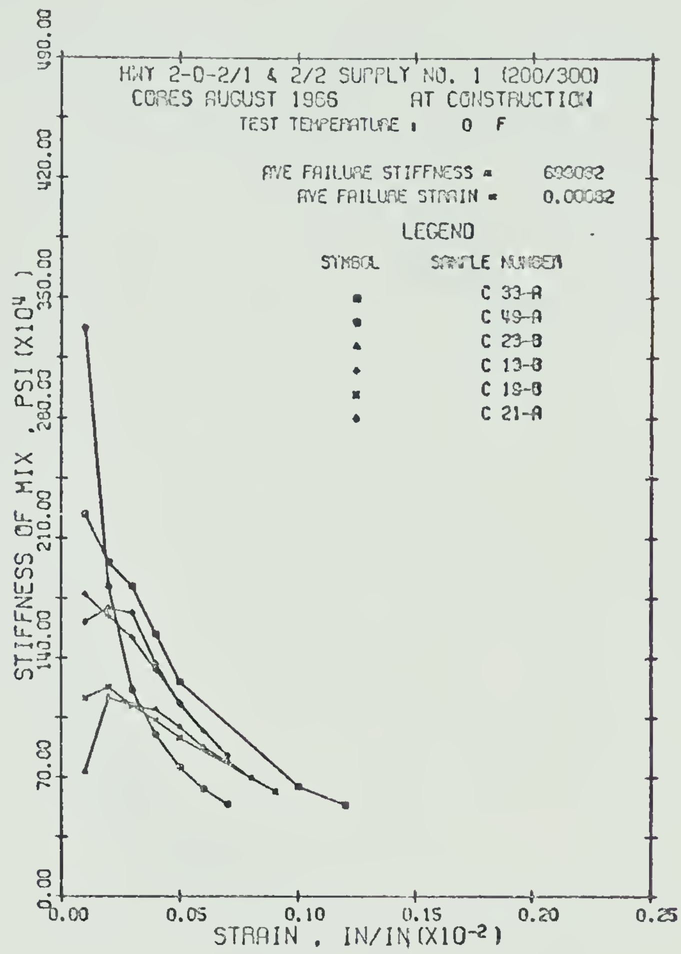


FIG. B2(b)

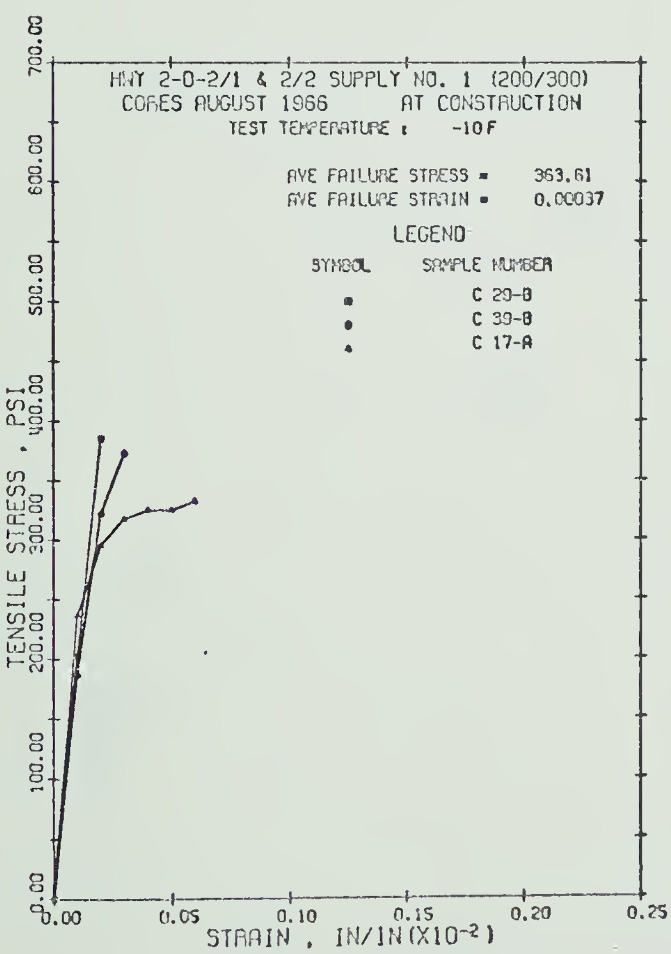


FIG. B2(c)

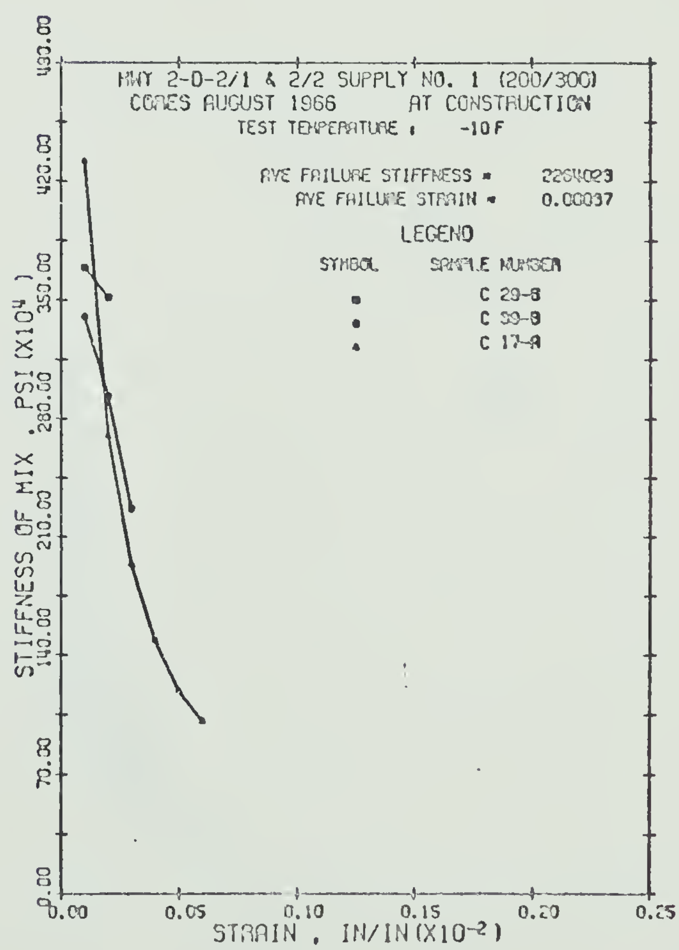


FIG. B2(d)

FIGURE B2: Supply No. 1 - At Construction

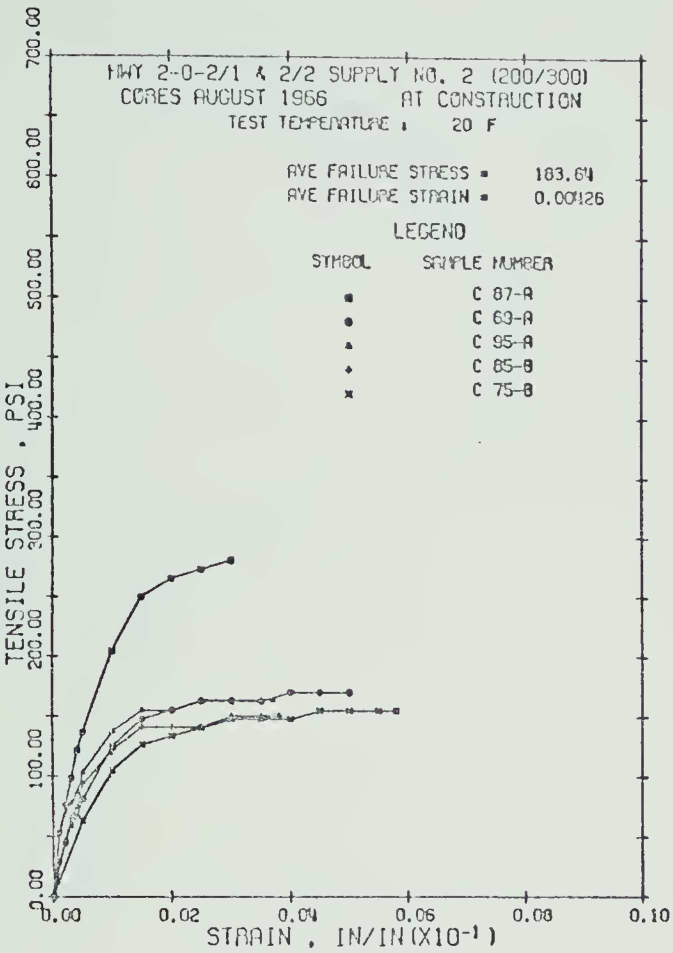


FIG. B3(a)

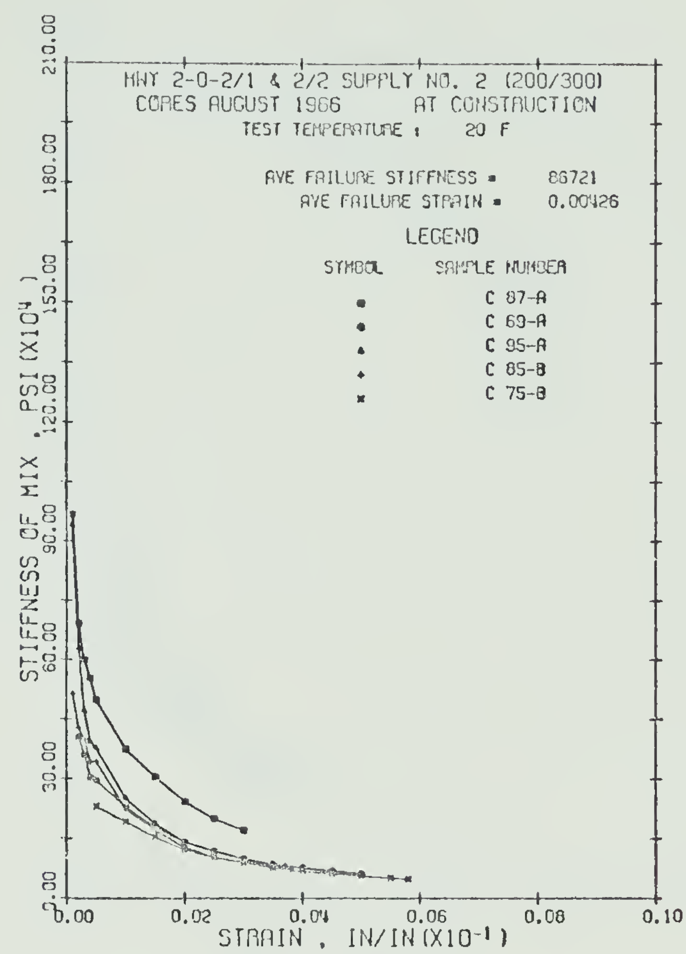


FIG. B3(b)

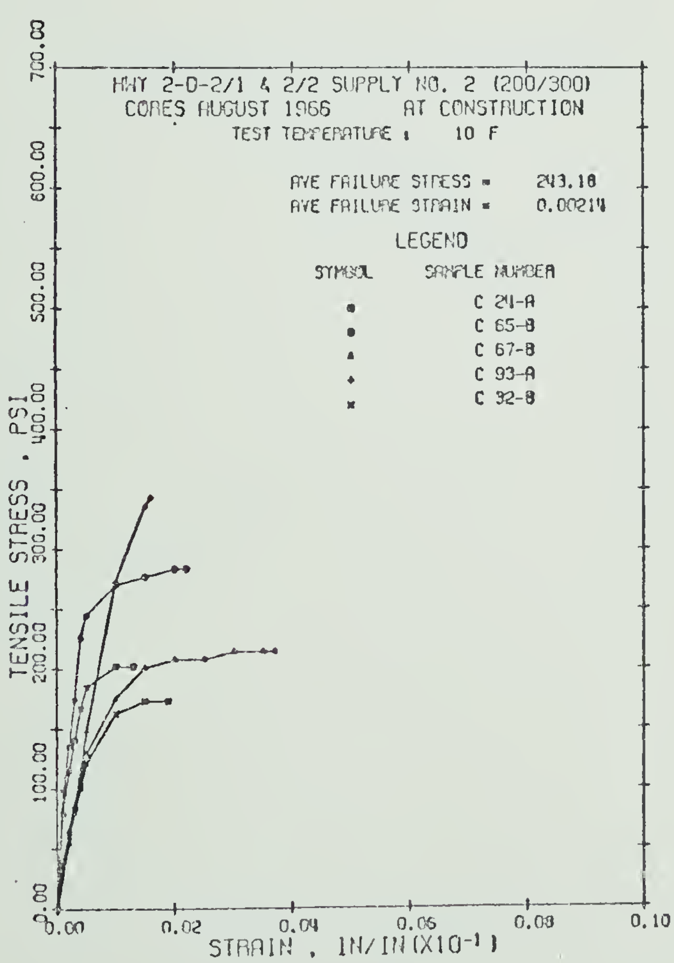


FIG. B3(c)

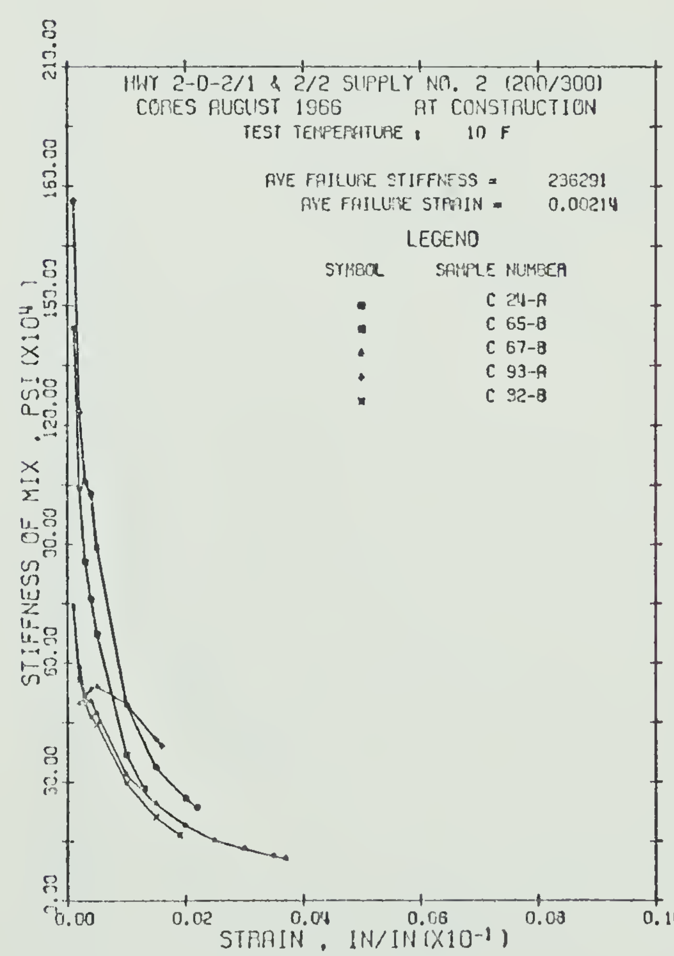


FIG. B3(d)

FIGURE B3: Supply No. 2 - At Construction

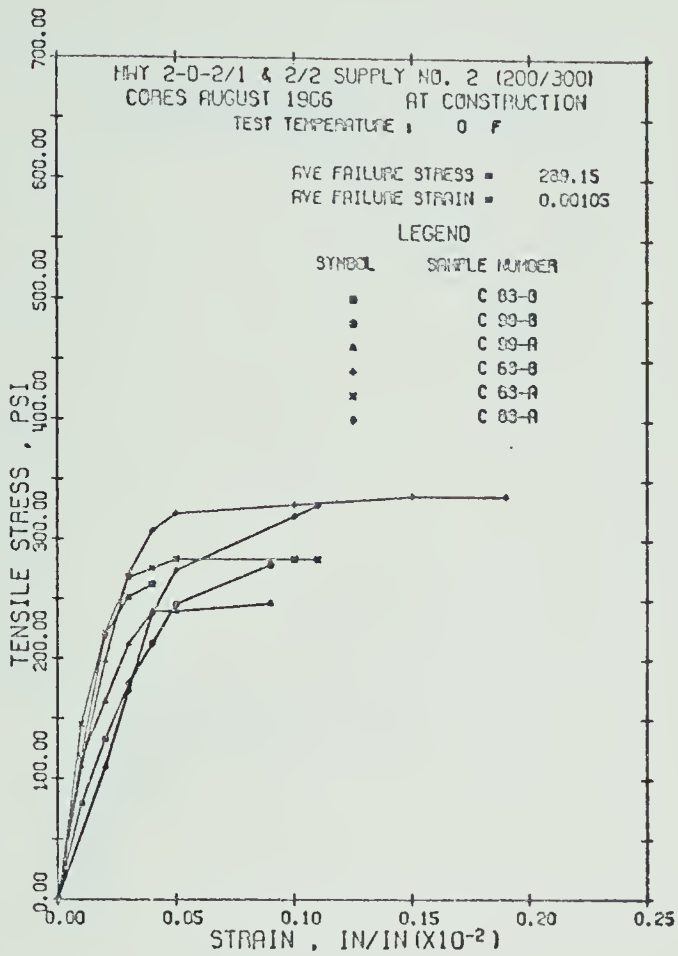


FIG. B4(a)

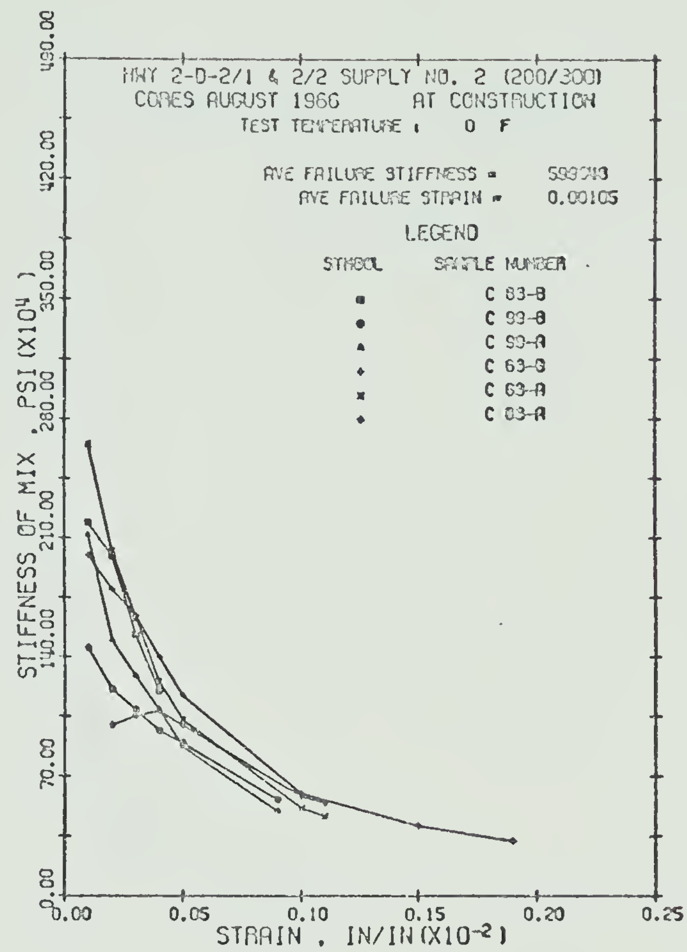


FIG. B4(b)

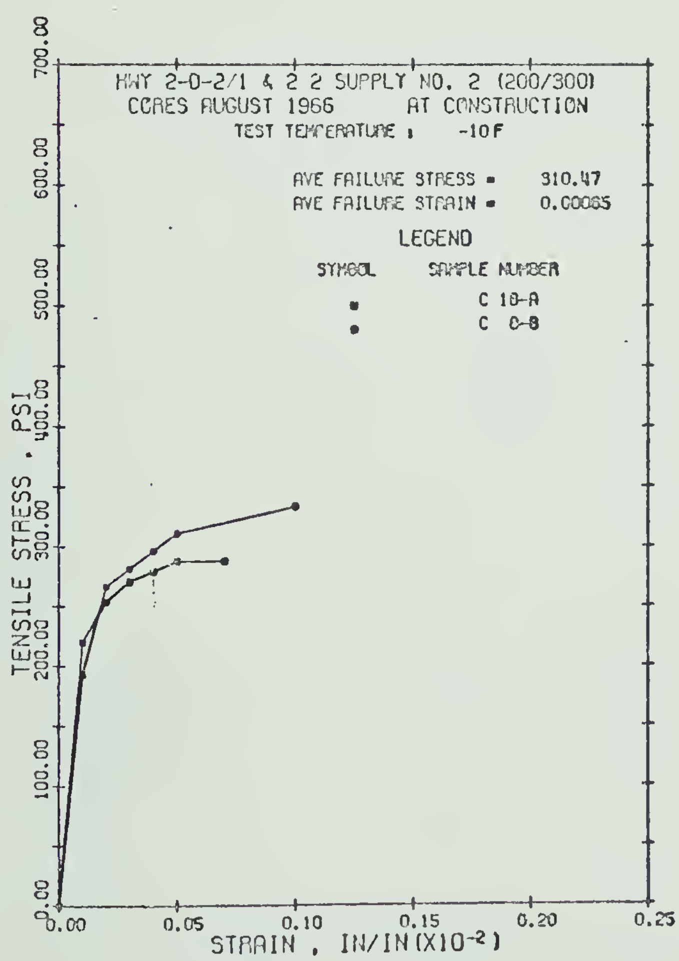


FIG. B4(c)

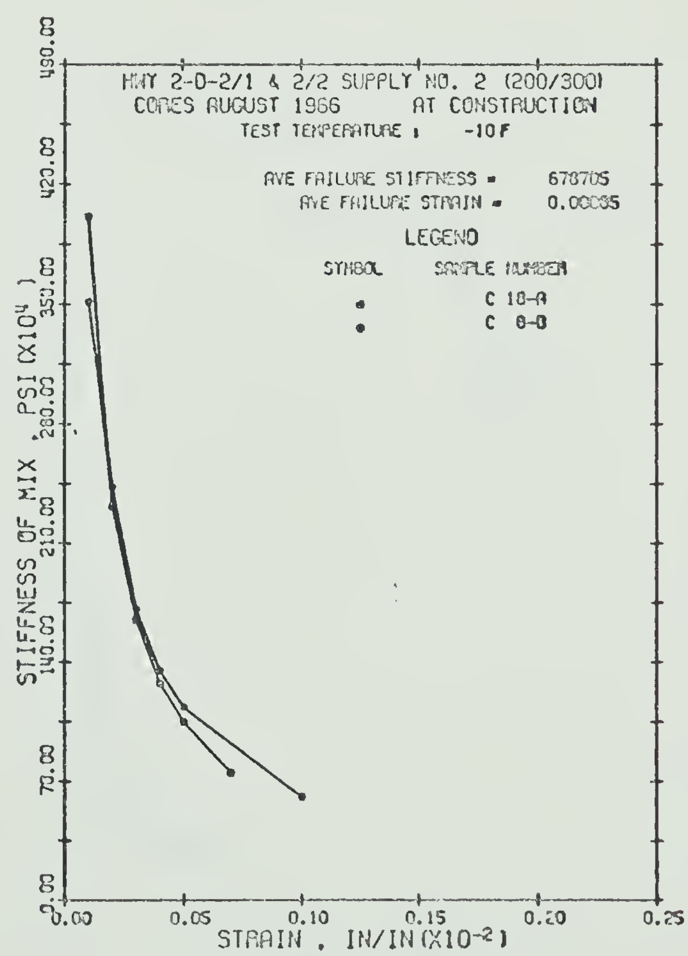


FIG. B4(d)

FIGURE B4: Supply No. 2 - At Construction

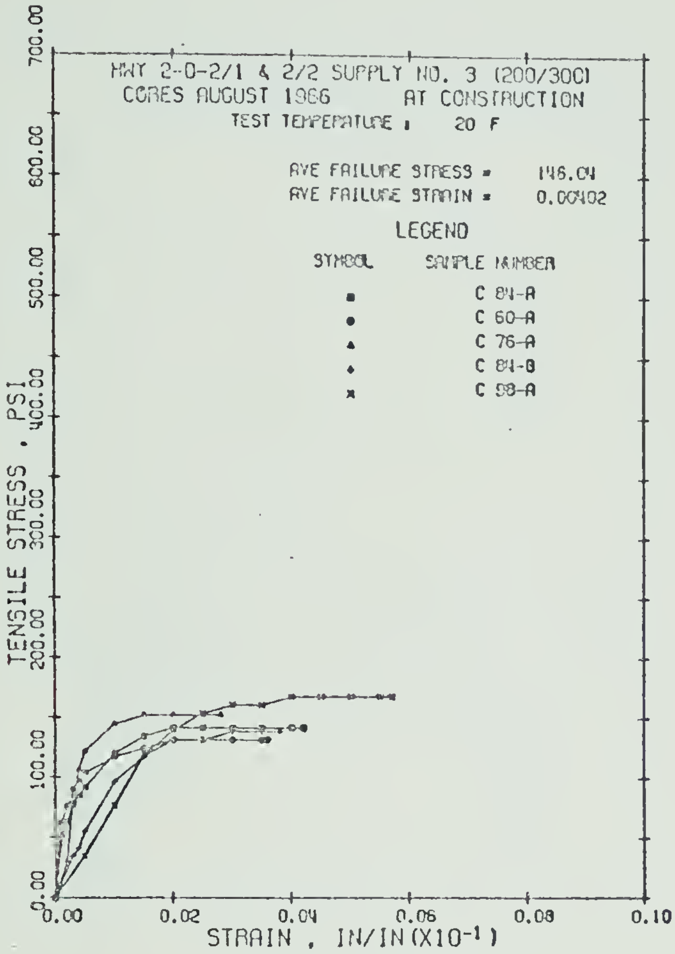


FIG. B5(a)

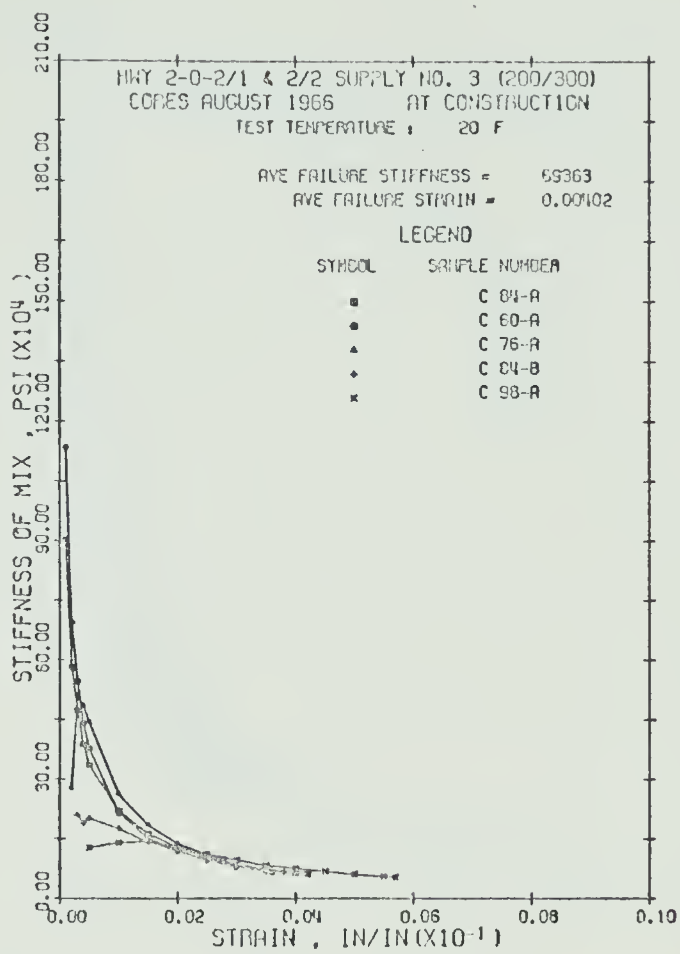


FIG. B5(b)

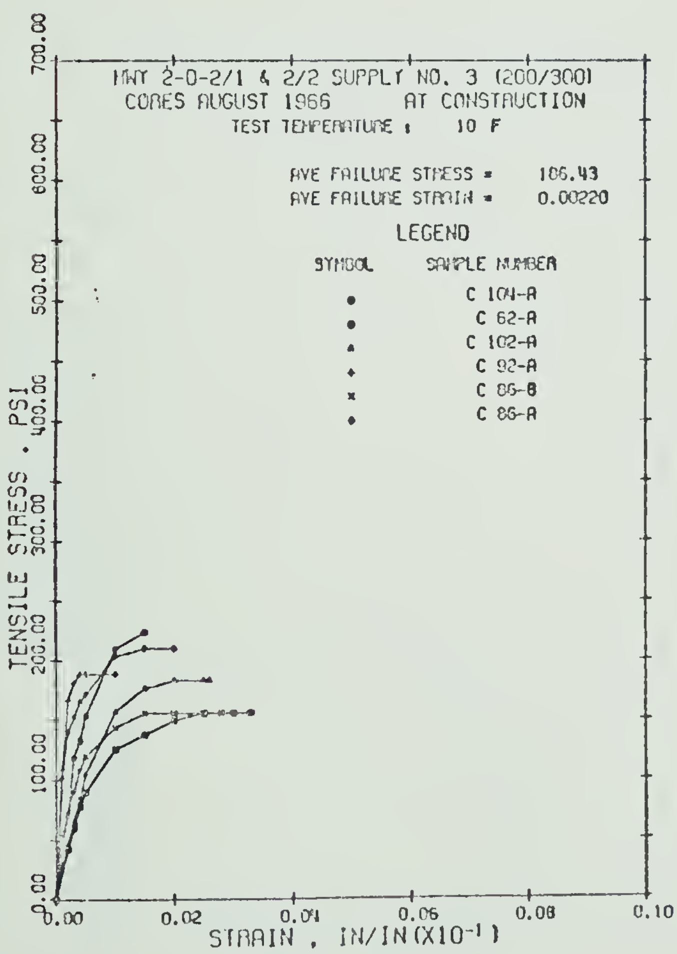


FIG. B5(c)

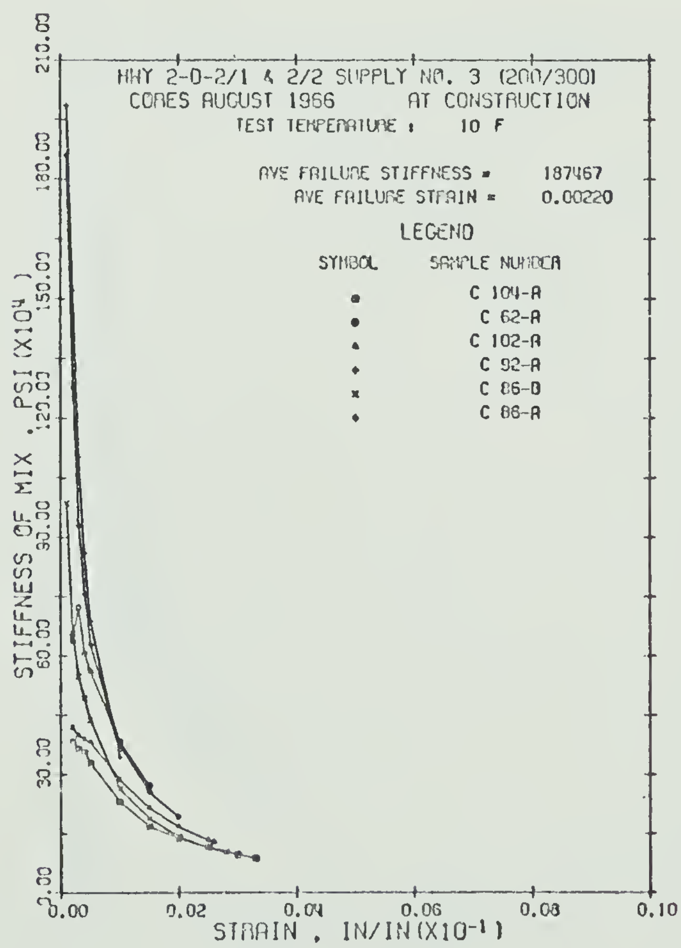


FIG. B5(d)

FIGURE B5: Supply No. 3 - At Construction

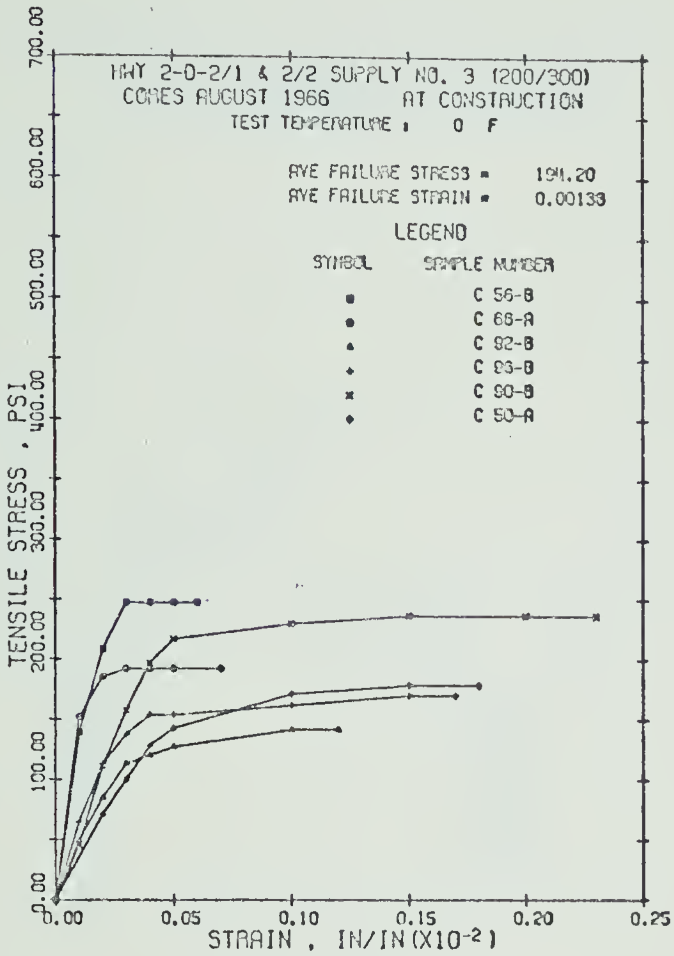


FIG. B6(a)

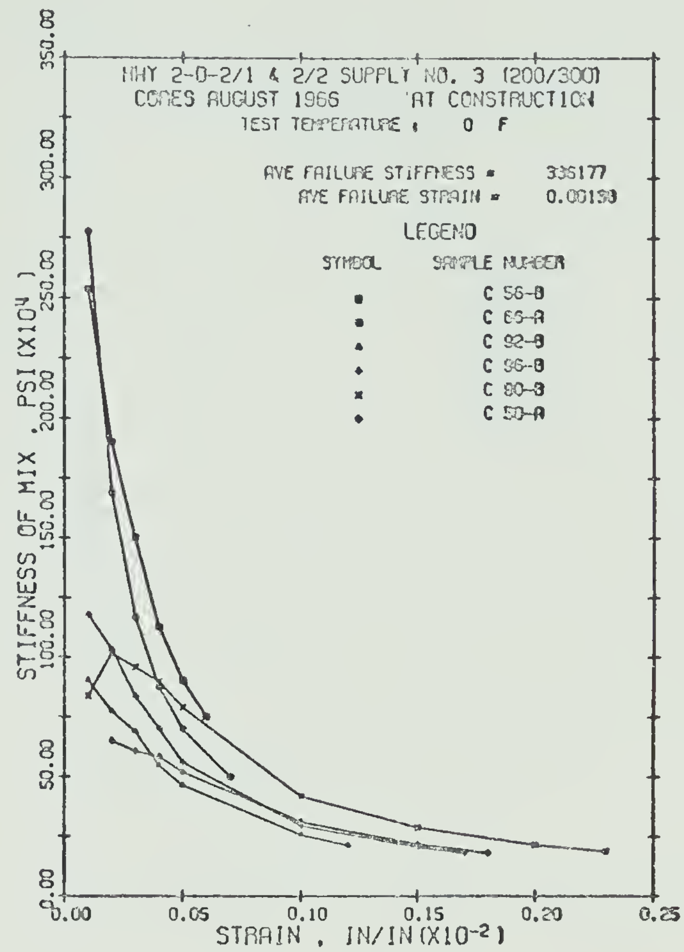


FIG. B6(b)

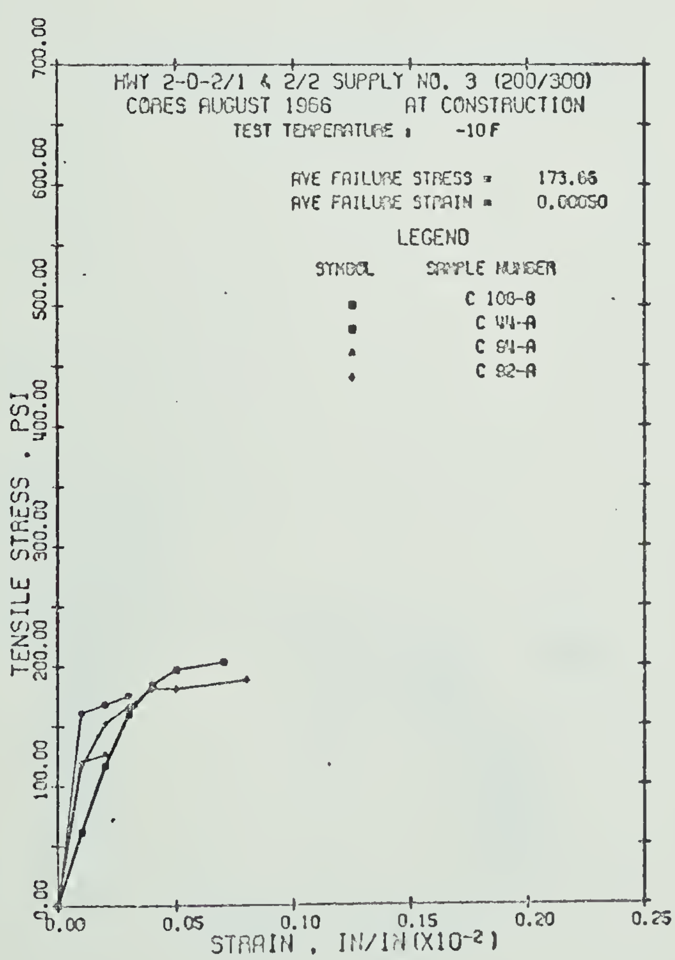


FIG. B6(c)

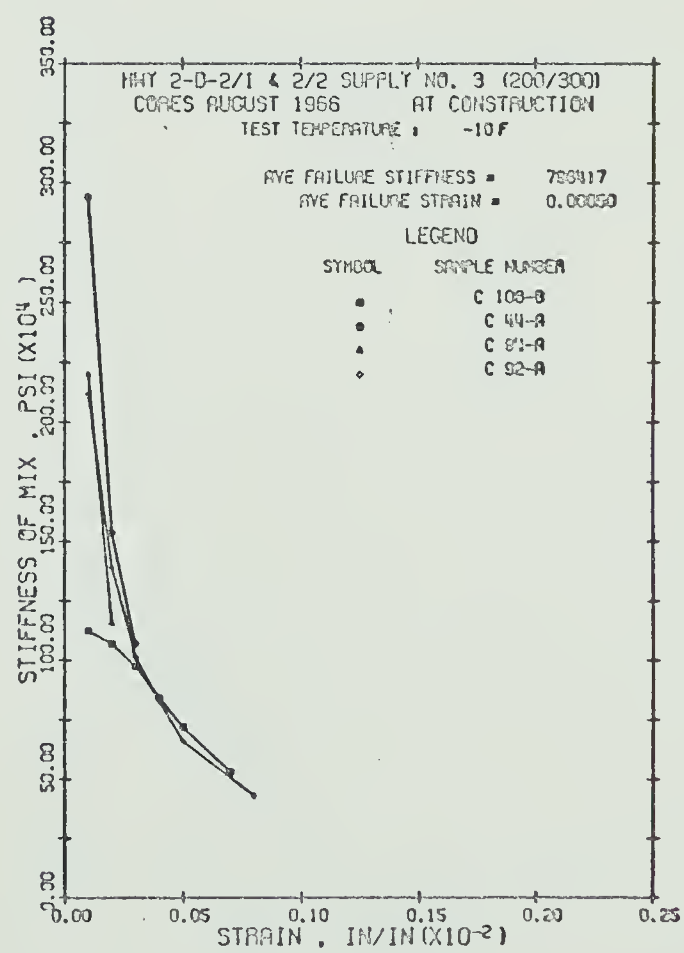


FIG. B6(d)

FIGURE B6: Supply No. 3 - At Construction

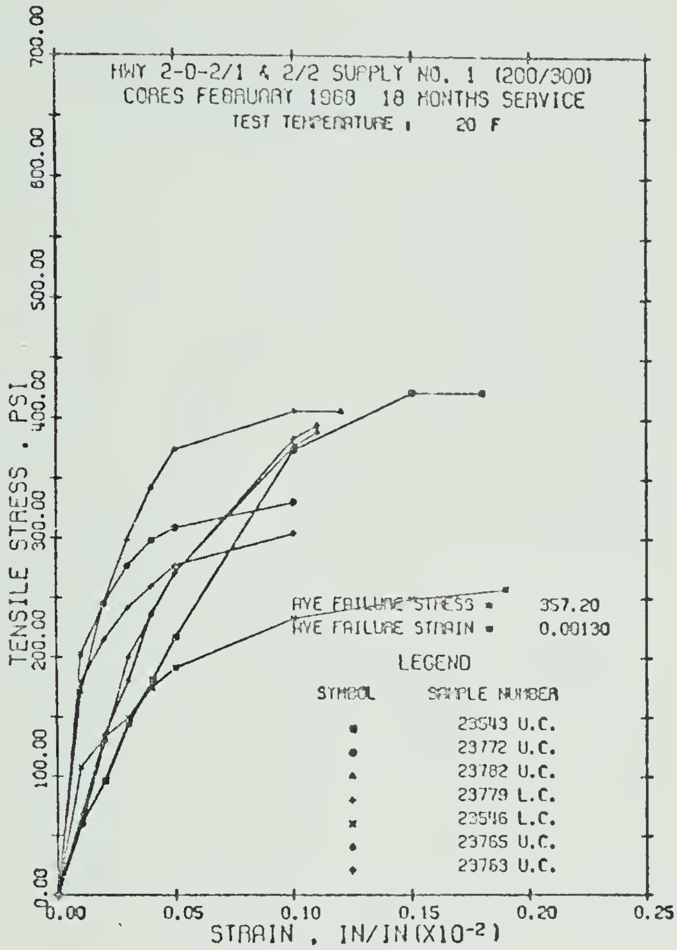


FIG. B7 (a)

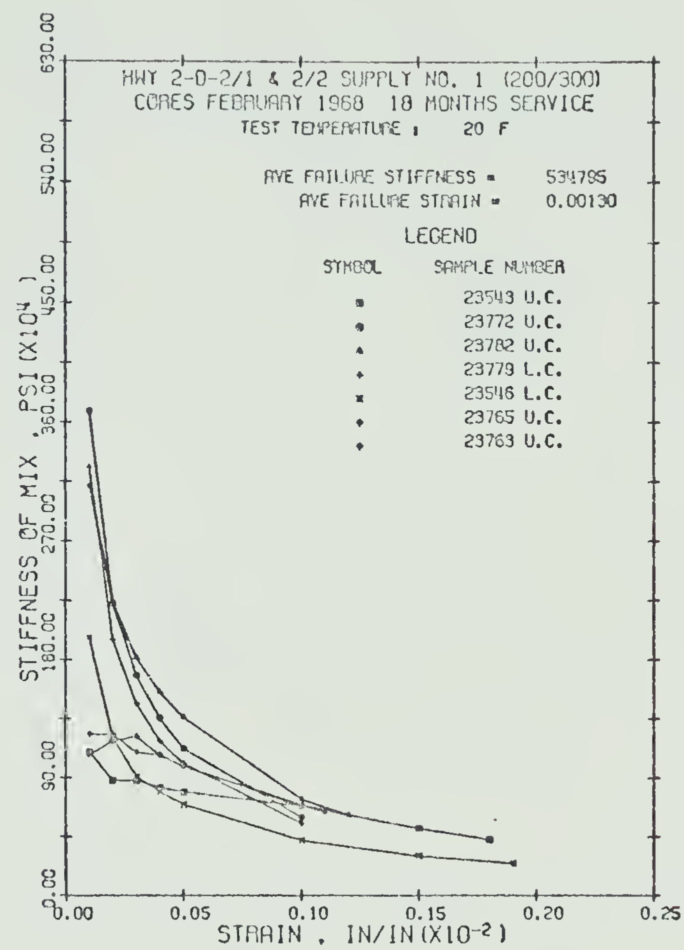


FIG. B7(b)

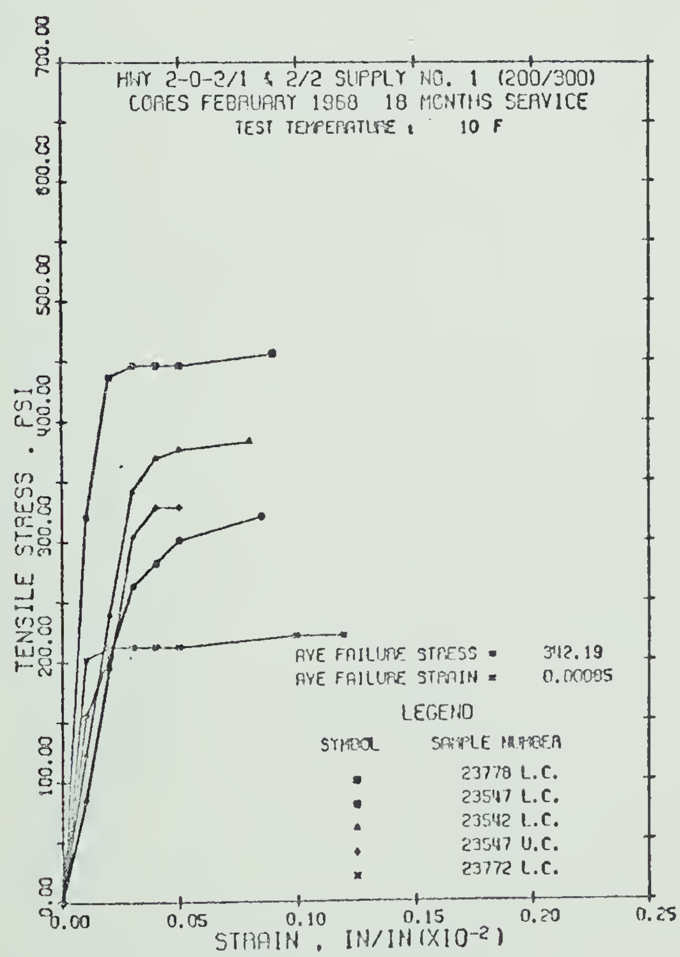


FIG. B7(c)

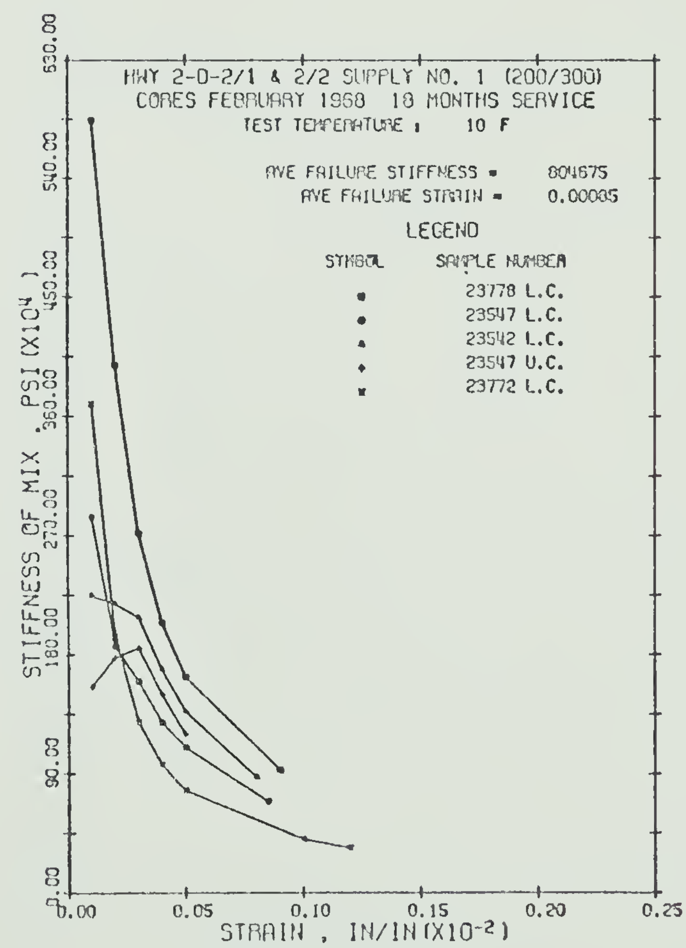


FIG. B7(d)

FIGURE B7: Supply No. 1 - 18 Months Service

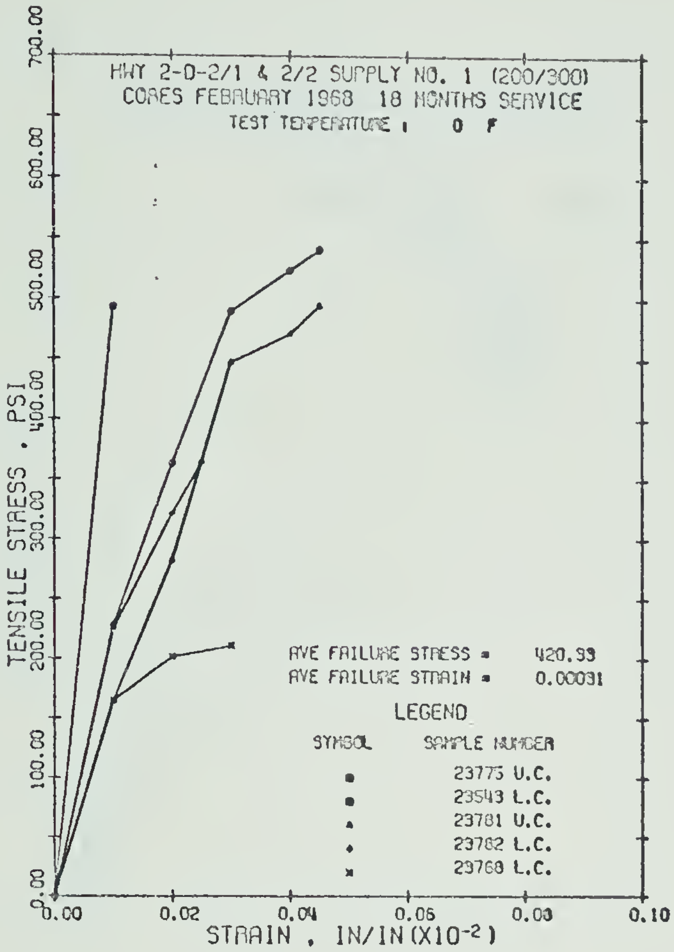


FIG. B8(a)

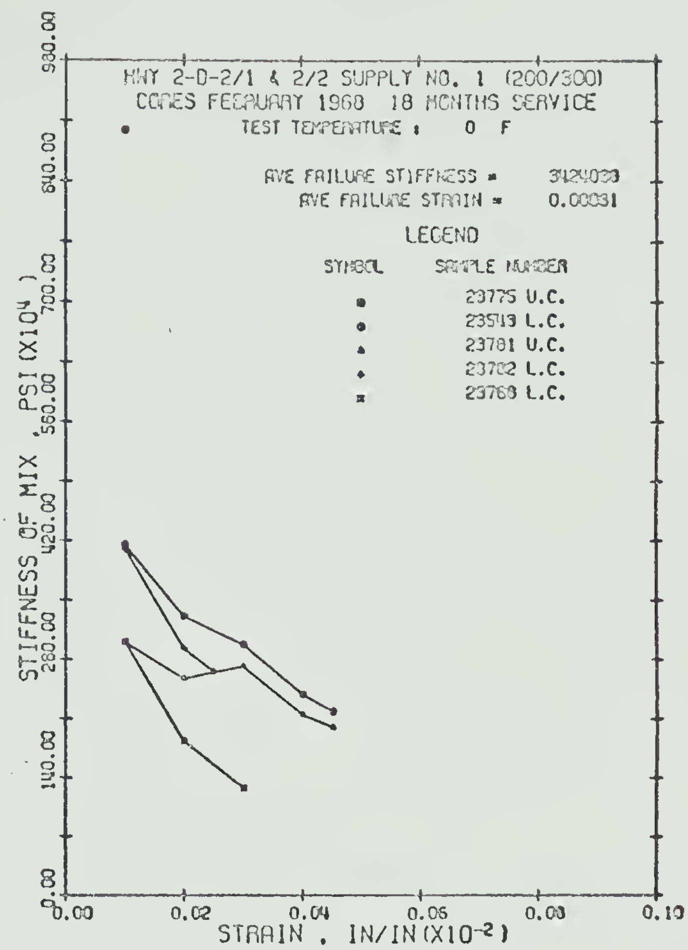


FIG. B8(b)

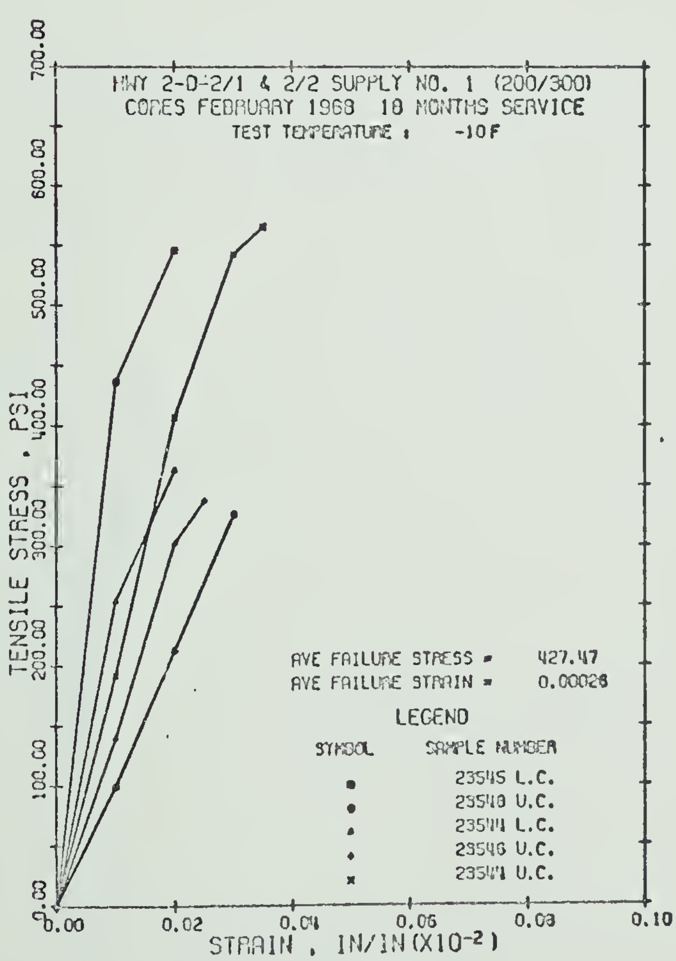


FIG. B8(c)

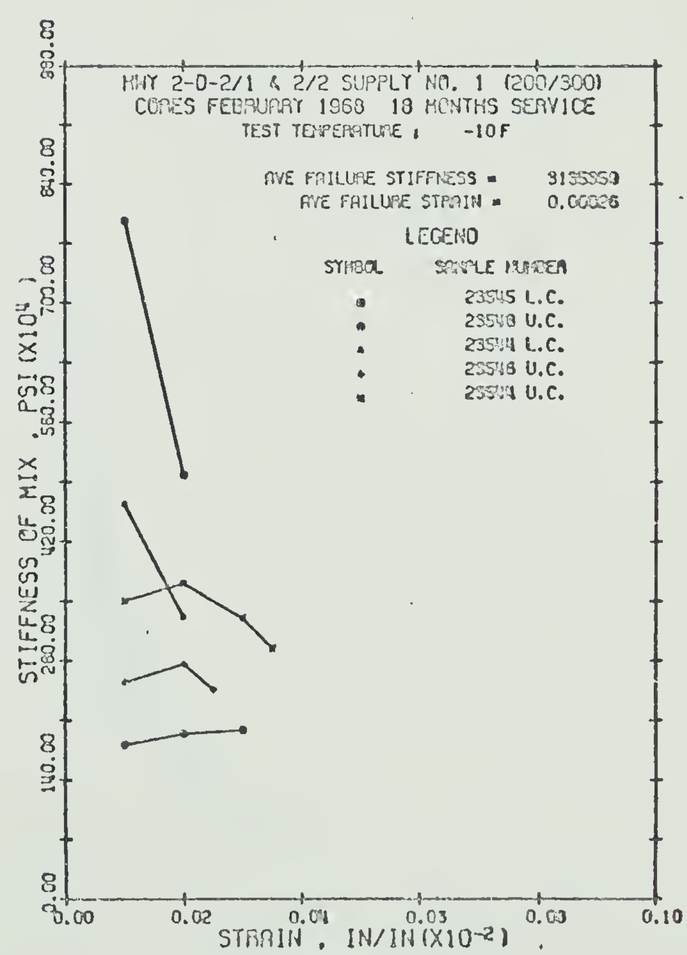


FIG. B8(d)

FIGURE B8: Supply No. 1 - 18 Months Service

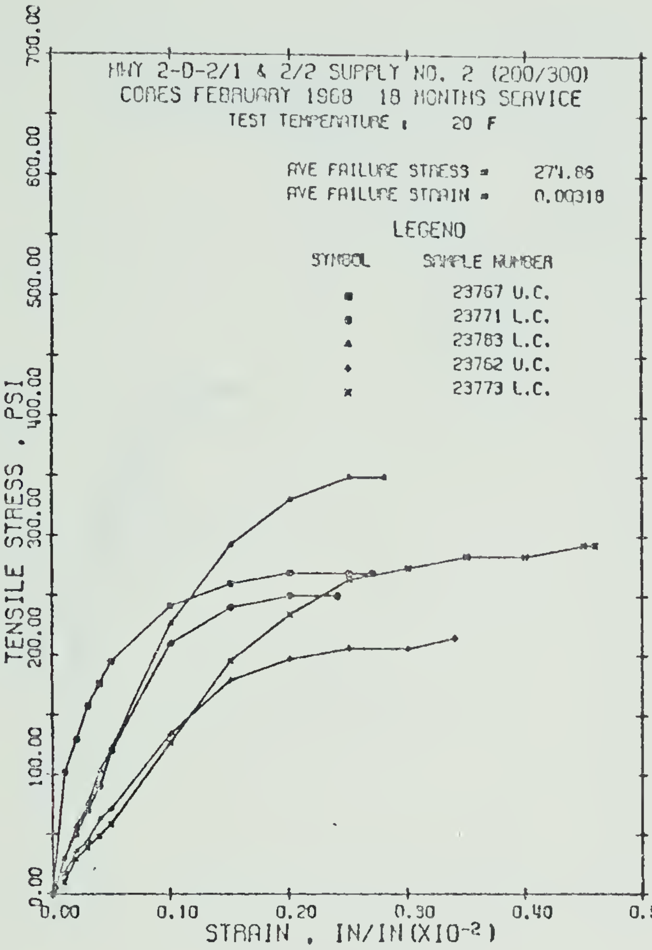


FIG. B9(a)

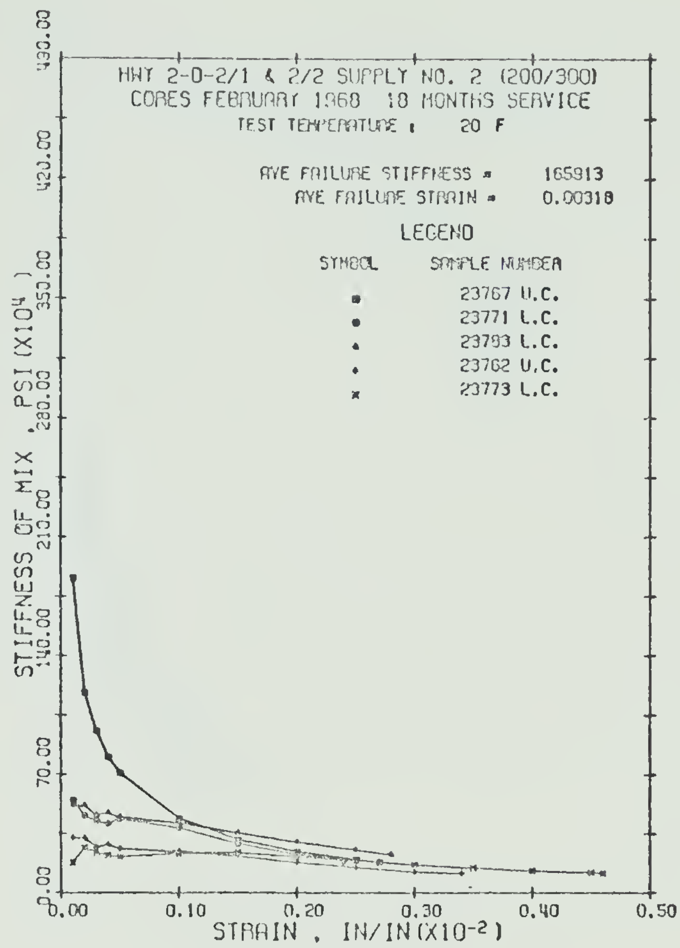


FIG. B9(b)

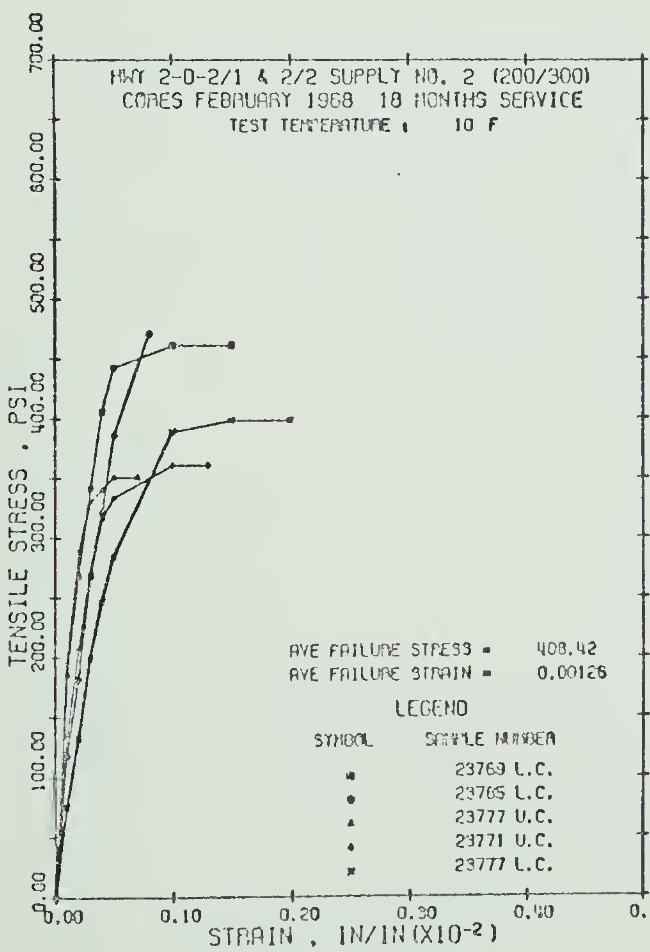


FIG. B9(c)

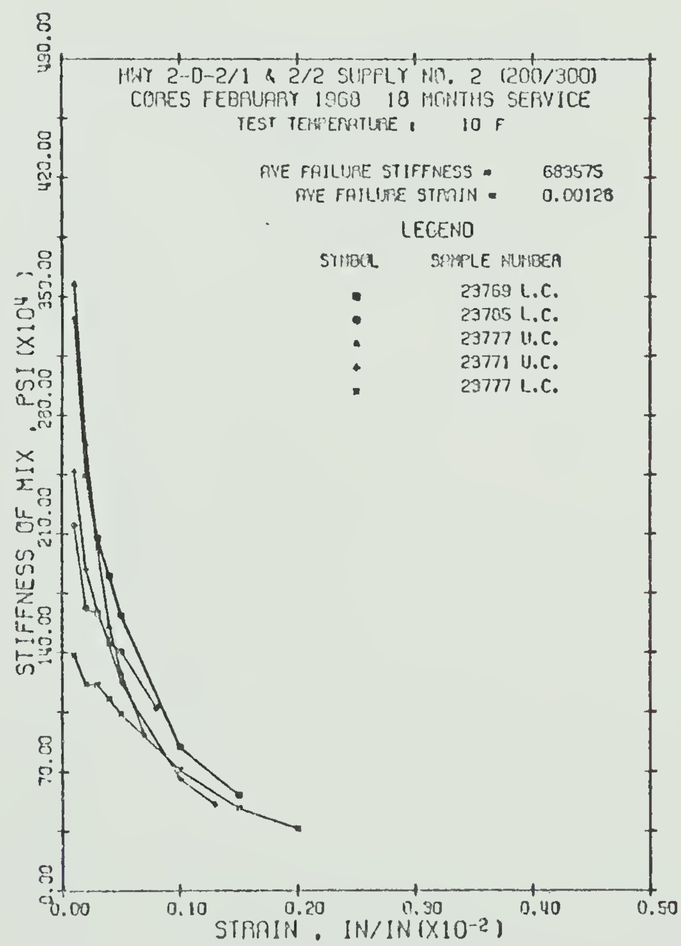


FIG. B9(d)

FIGURE B9: Supply No. 2 - 18 Months Service

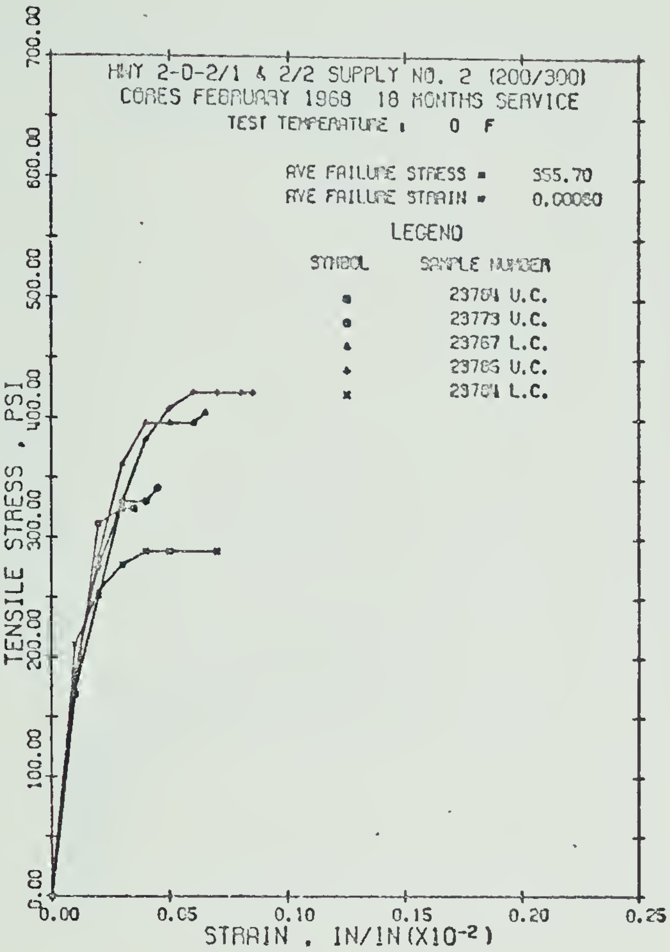


FIG. B10(a)

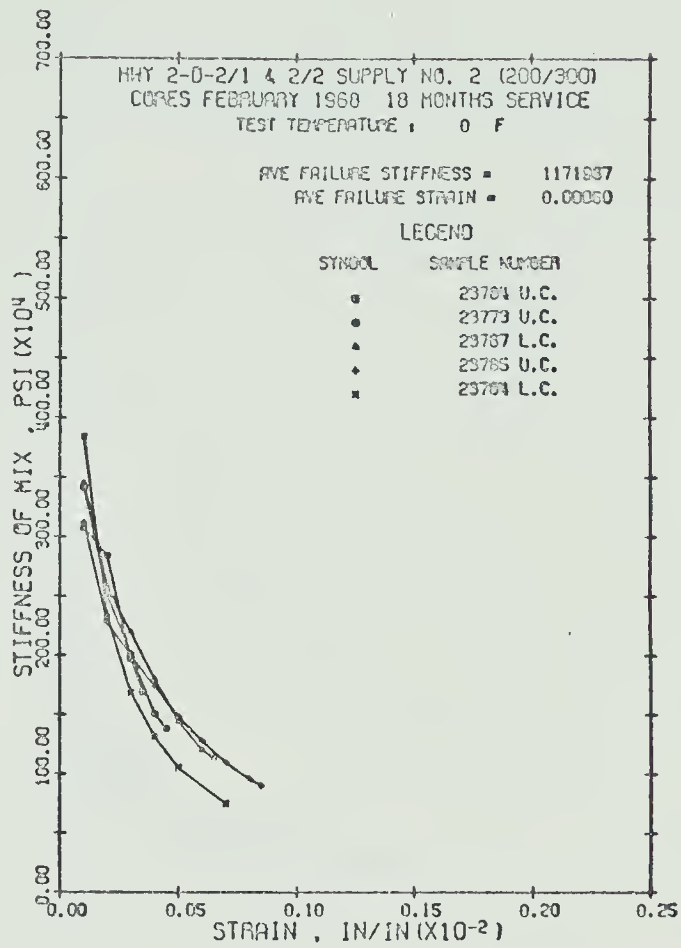


FIG. B10(b)

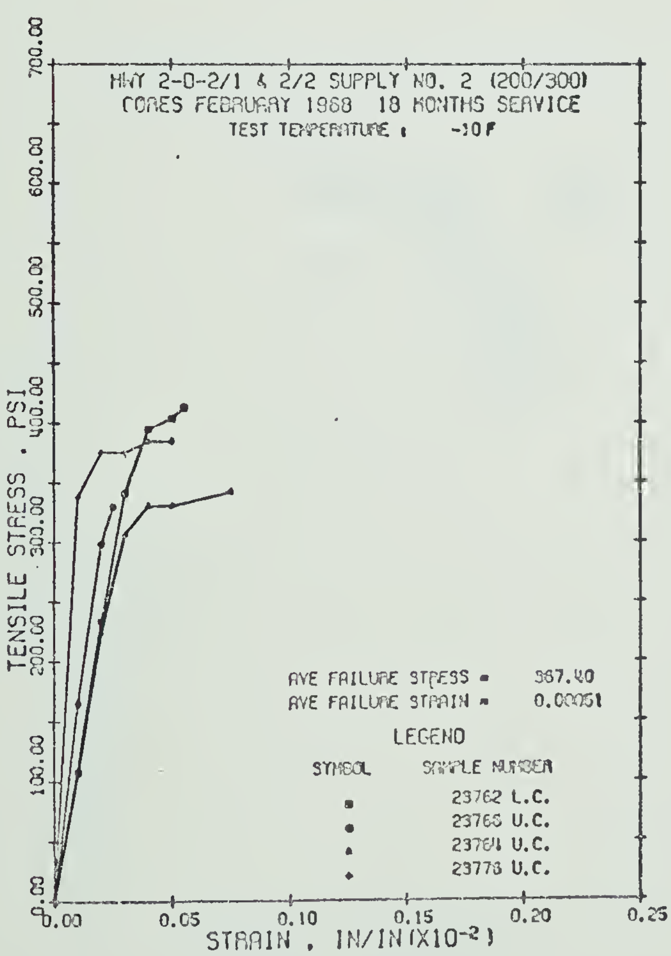


FIG. B10(c)

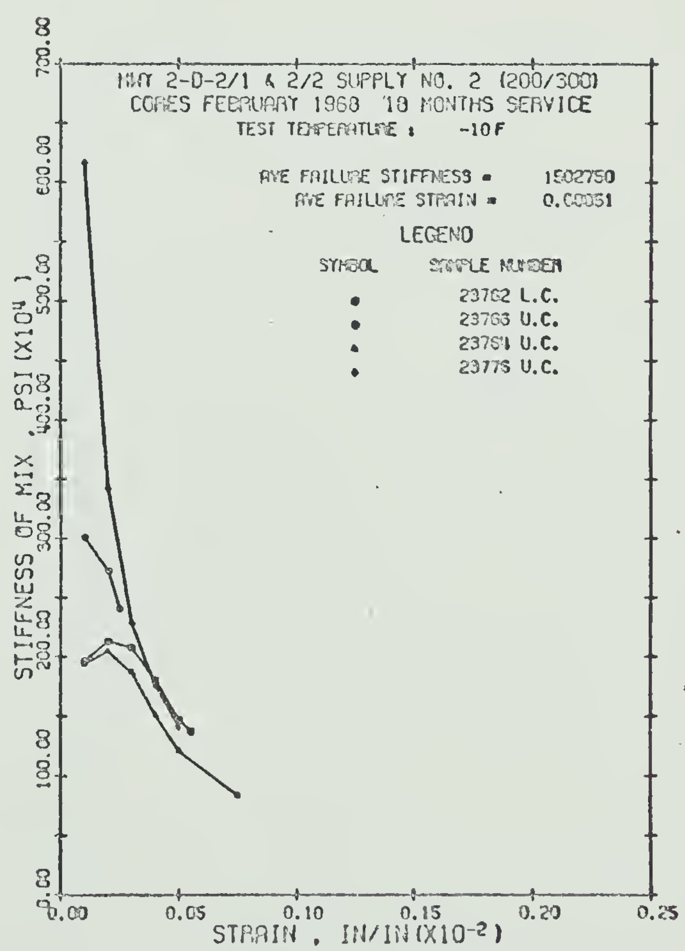


FIG. B10(d)

FIGURE B10: Supply No. 2 - 18 Months Service

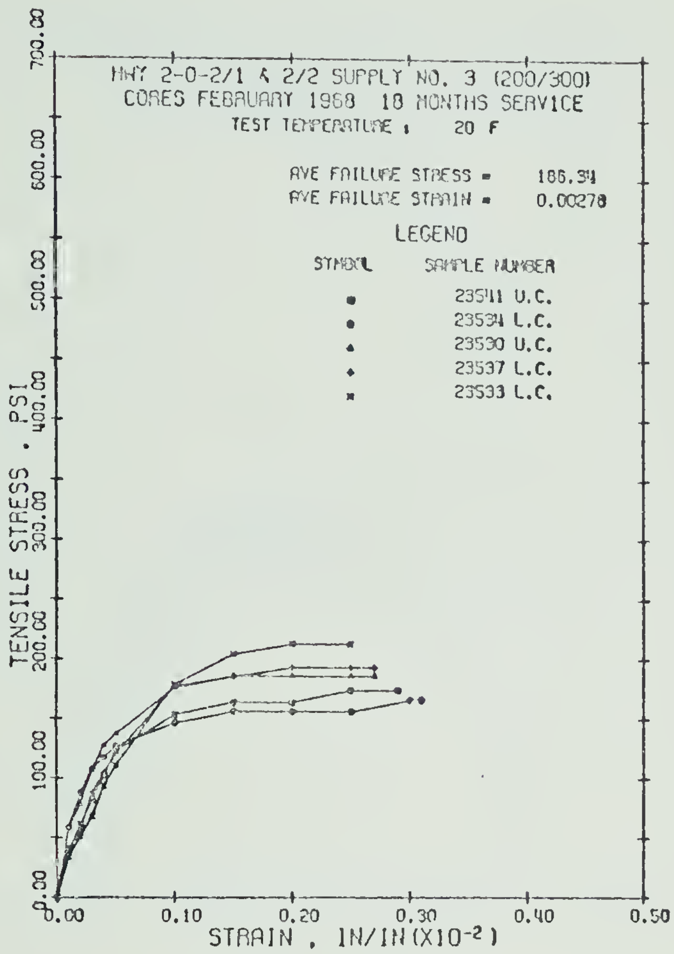


FIG. B11(a)

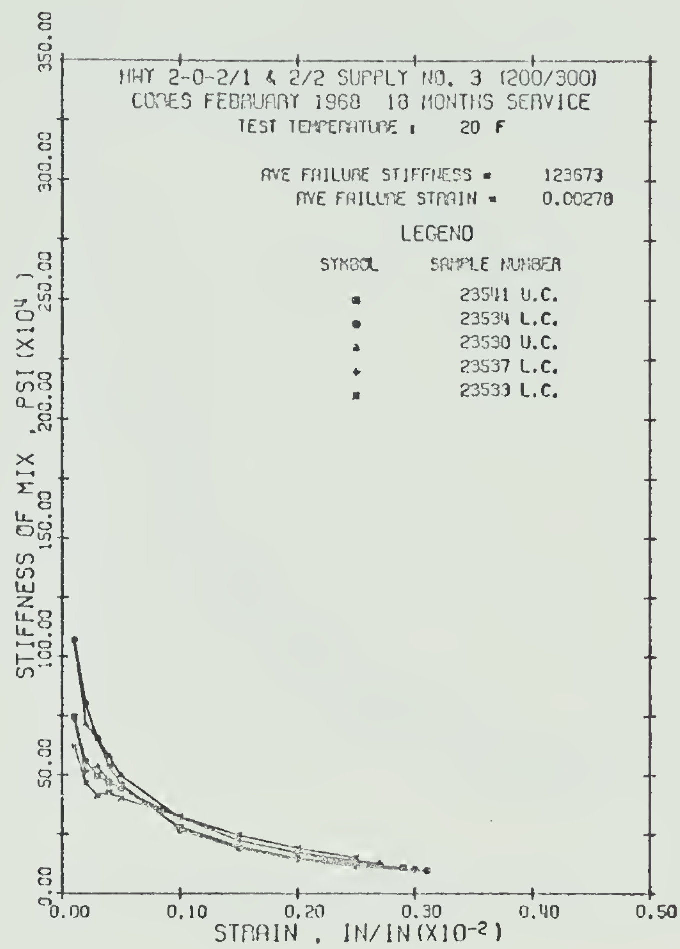


FIG. B11(b)

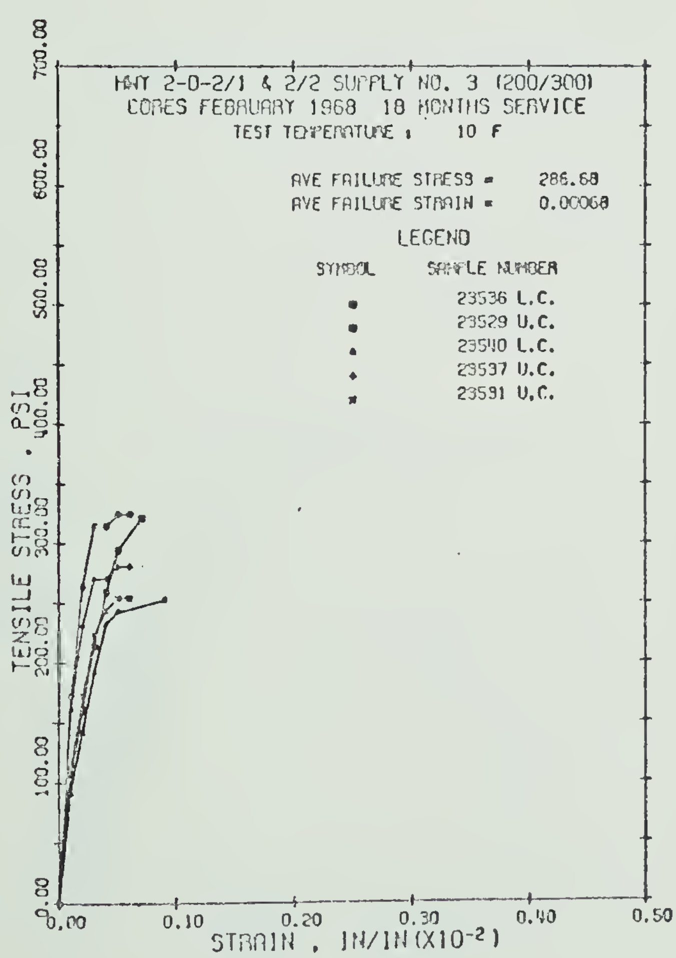


FIG. B11(c)

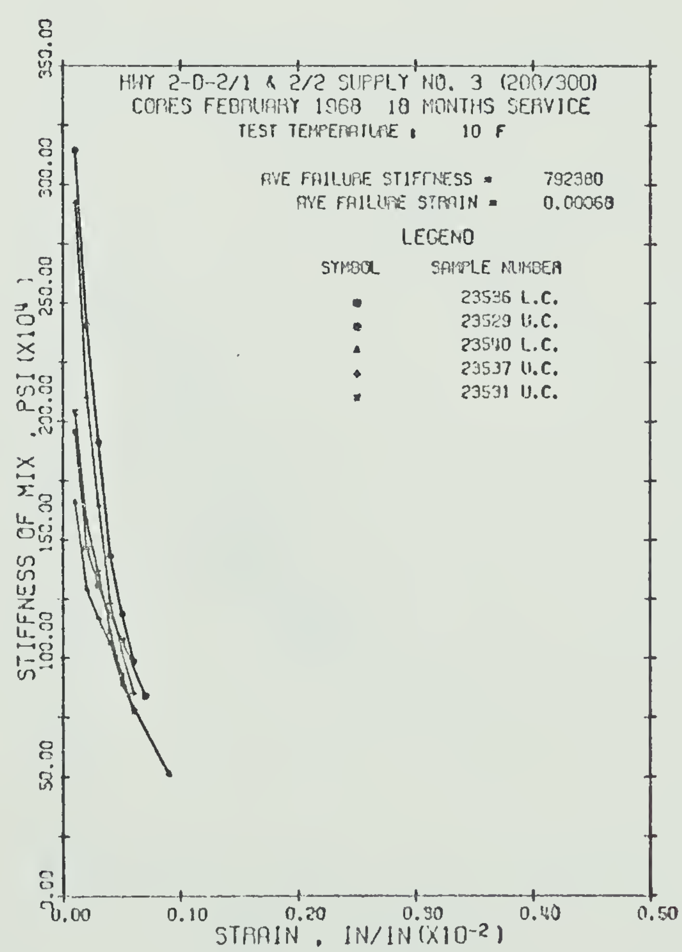


FIG. B11(d)

FIGURE B11: Supply No. 3 - 18 Months Service

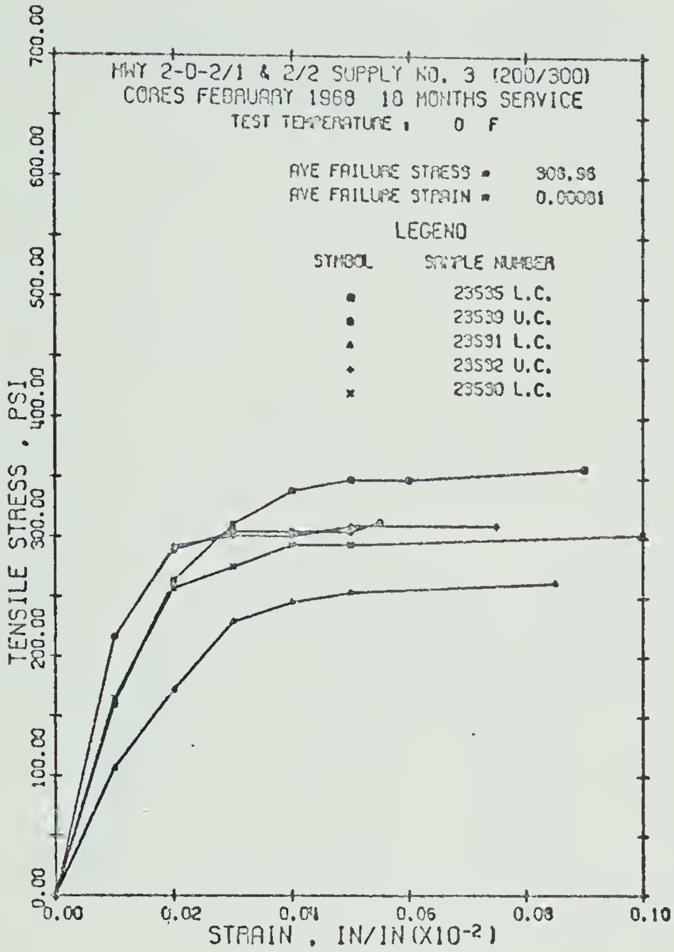


FIG. B12(a)

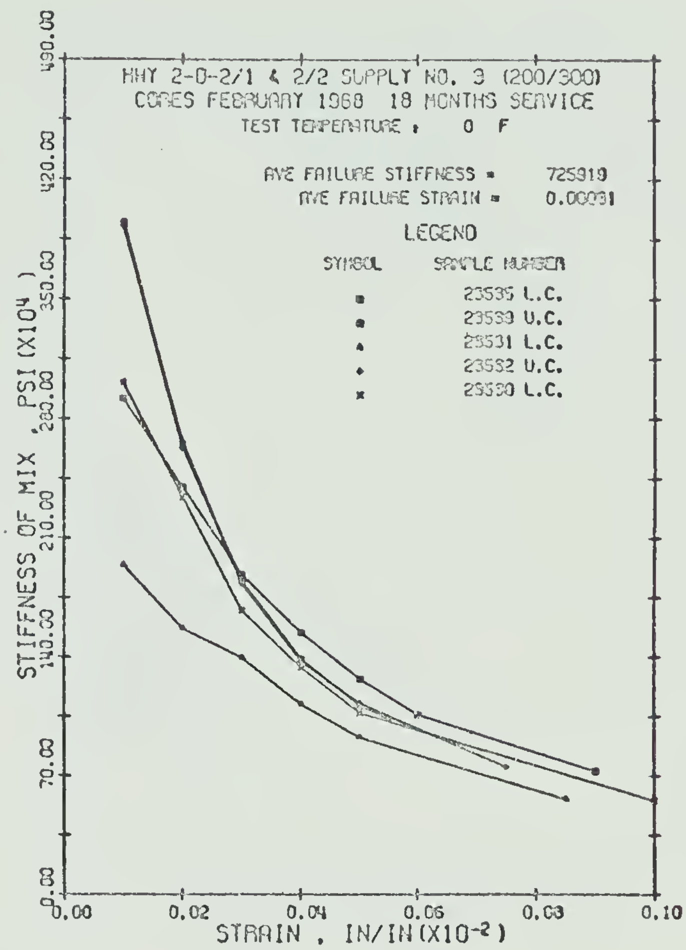


FIG. B12(b)

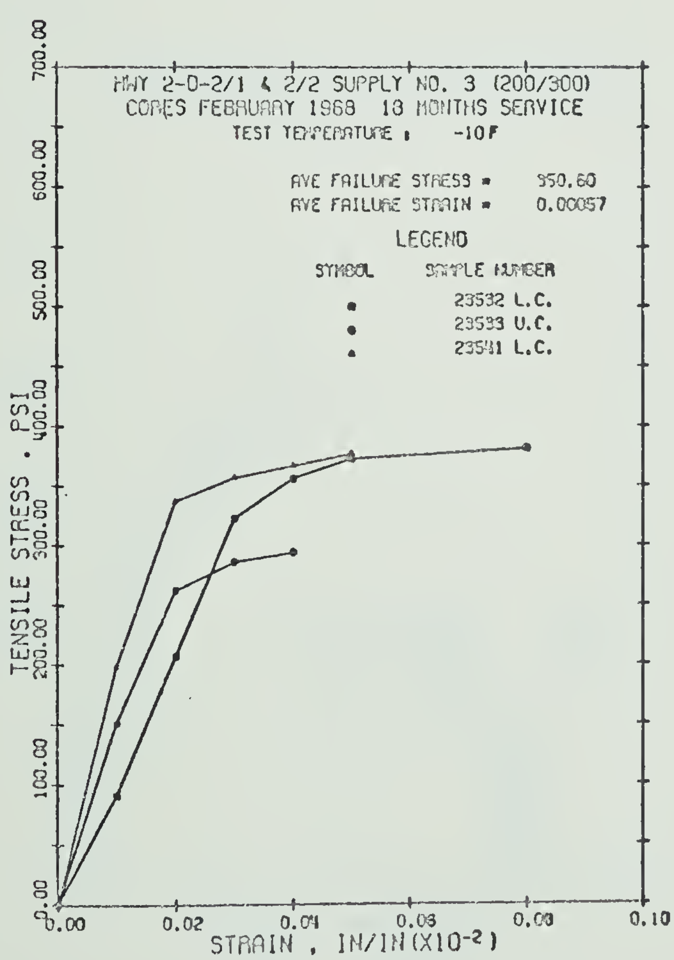


FIG. B12(c)

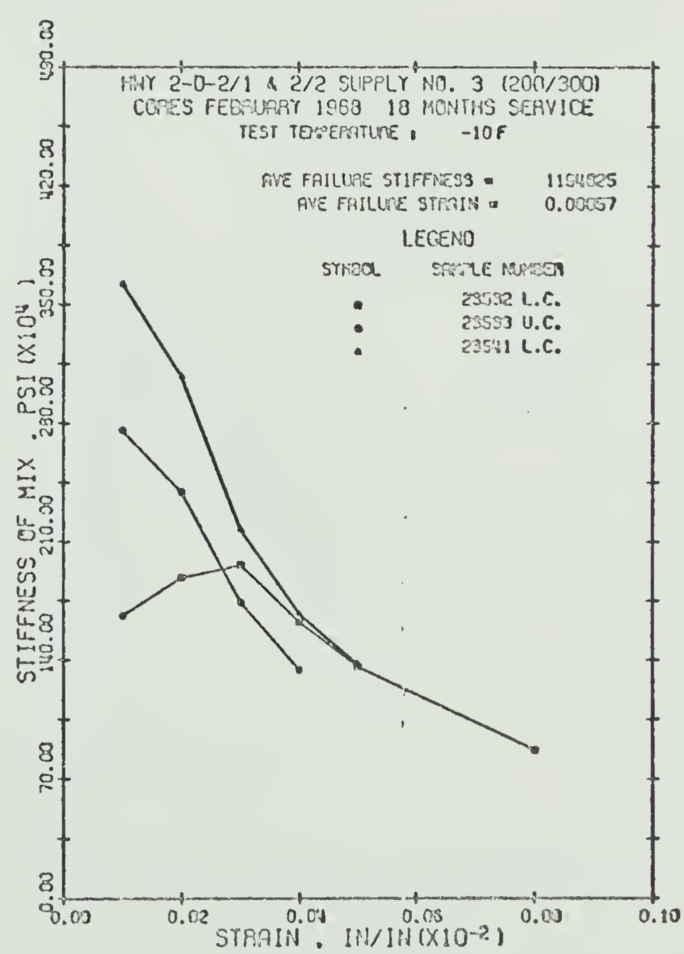


FIG. B12(d)

FIGURE B12: Supply No. 3 - 18 Months Service

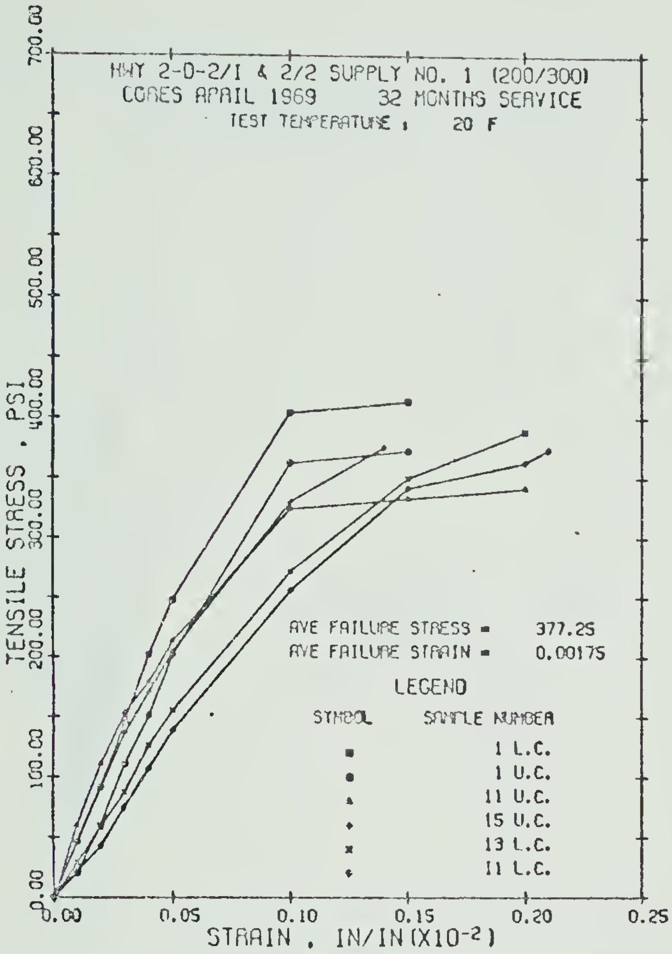


FIG. B13(a)

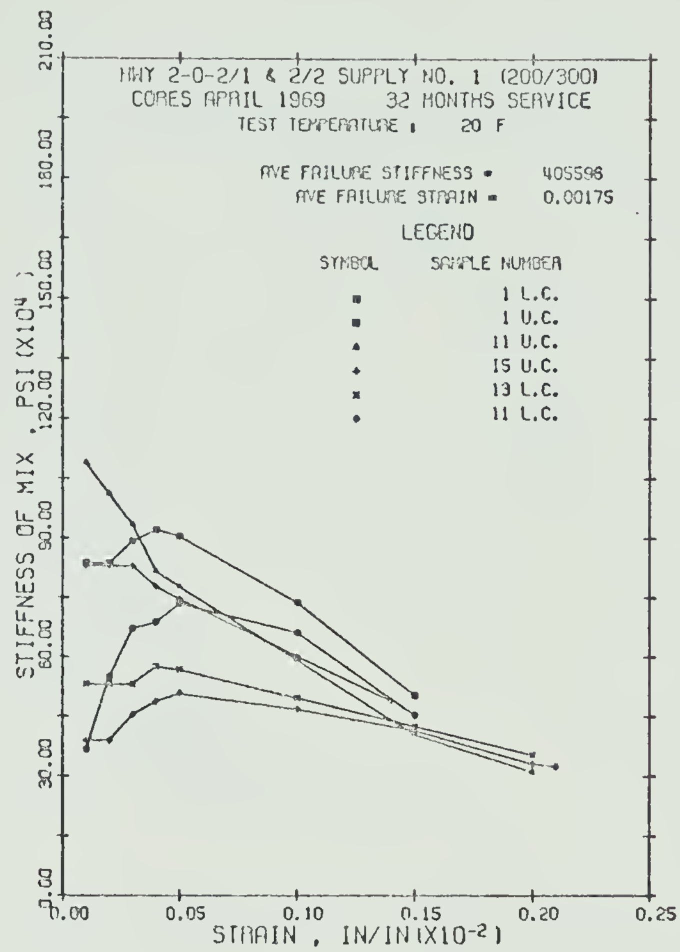


FIG. B13(b)

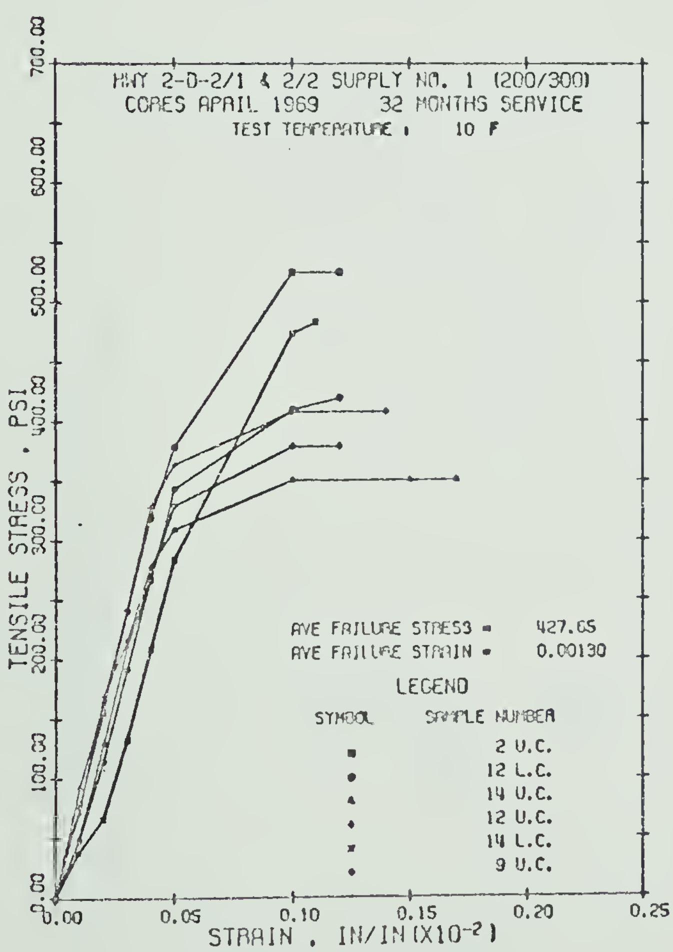


FIG. B13(c)

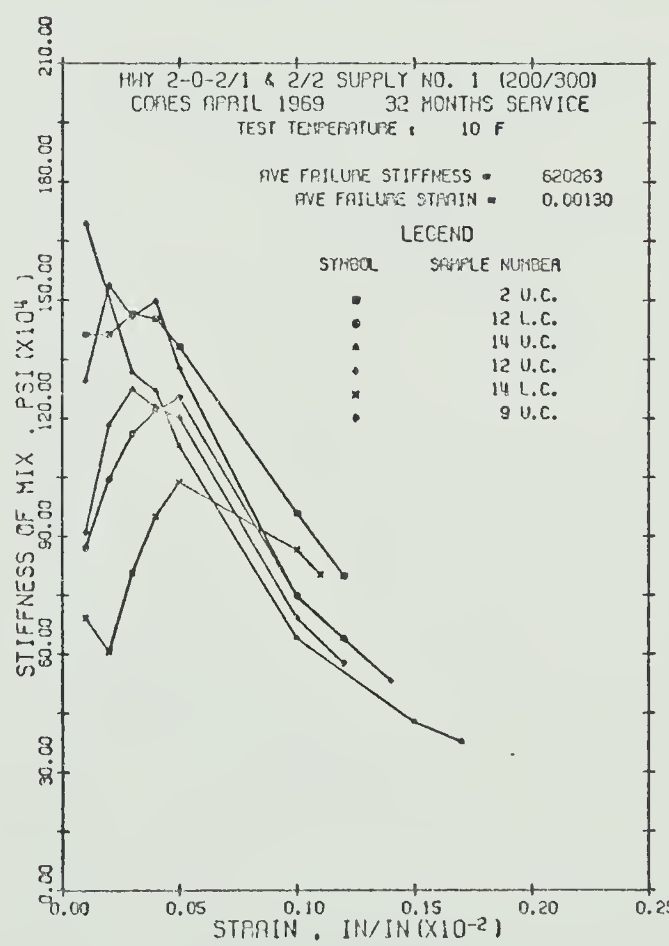


FIG. B13(d)

FIGURE B13: Supply No. 1 - 32 Months Service

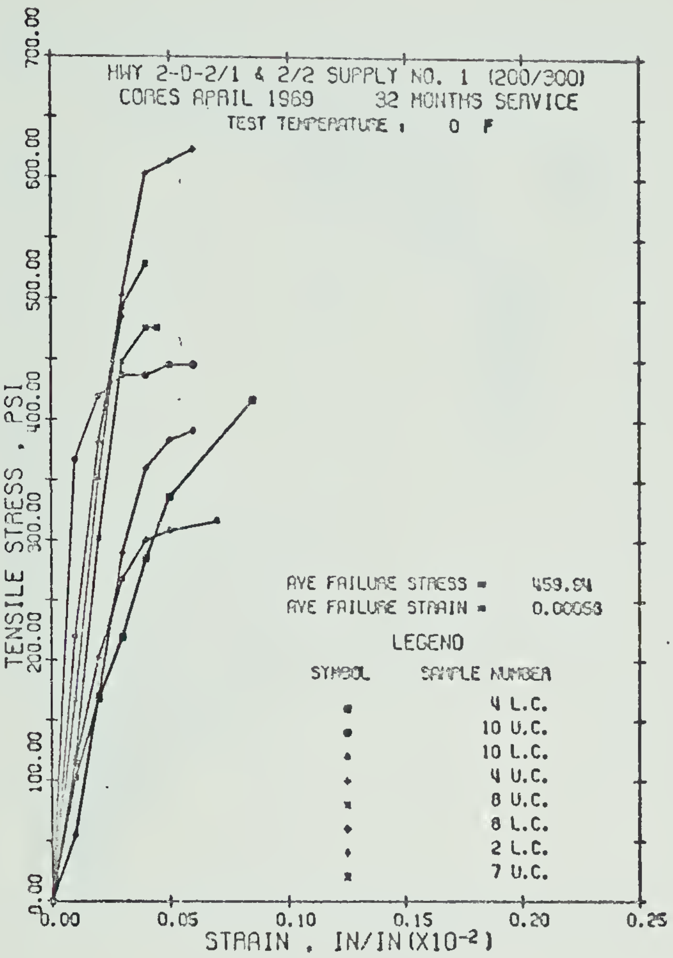


FIG. B14(a)

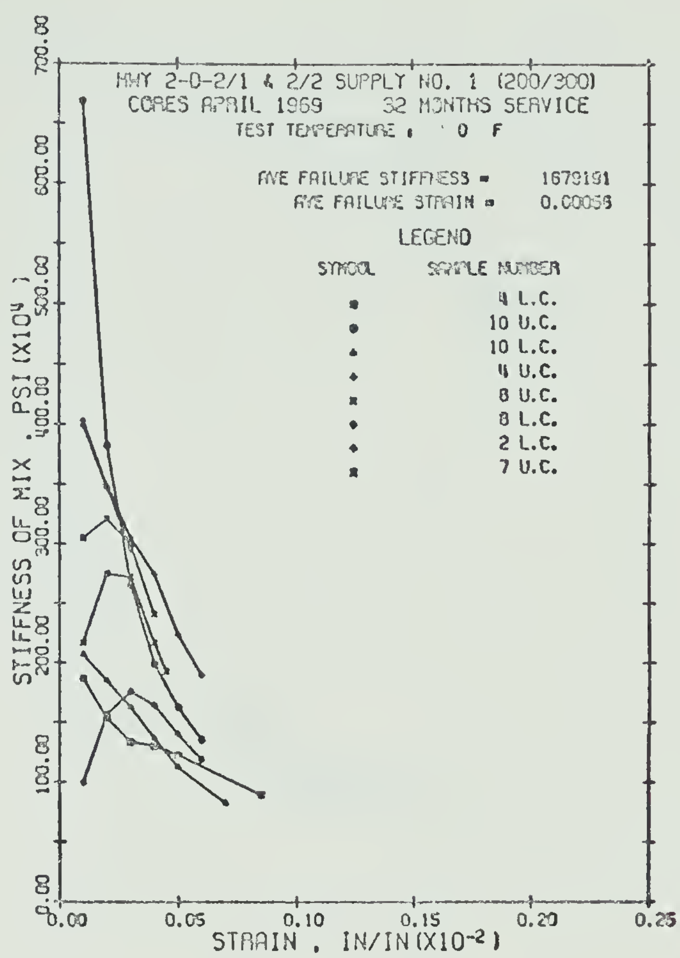


FIG. B14(b)

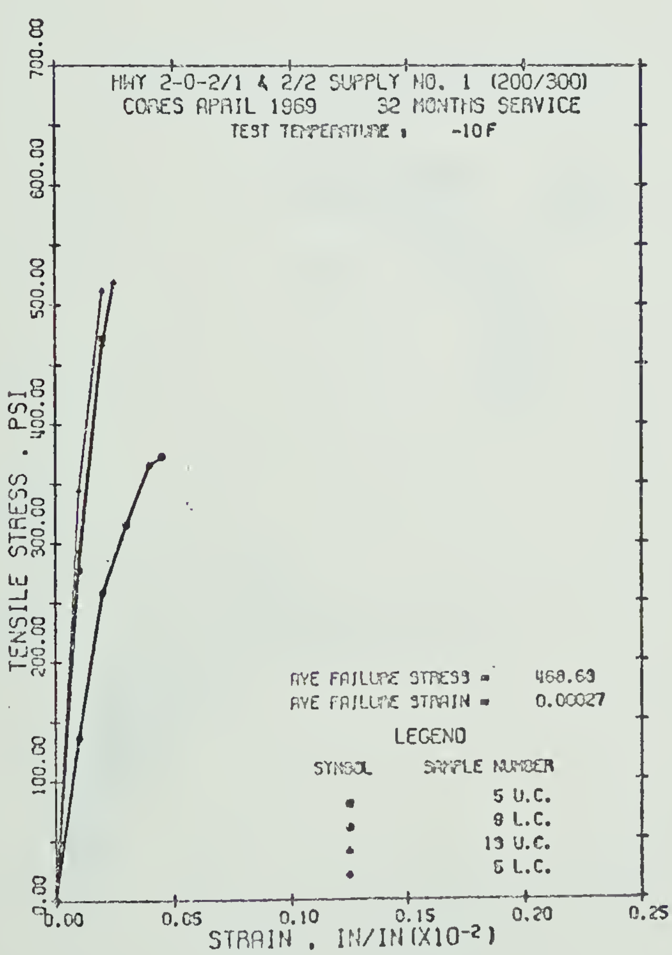


FIG. B14(c)

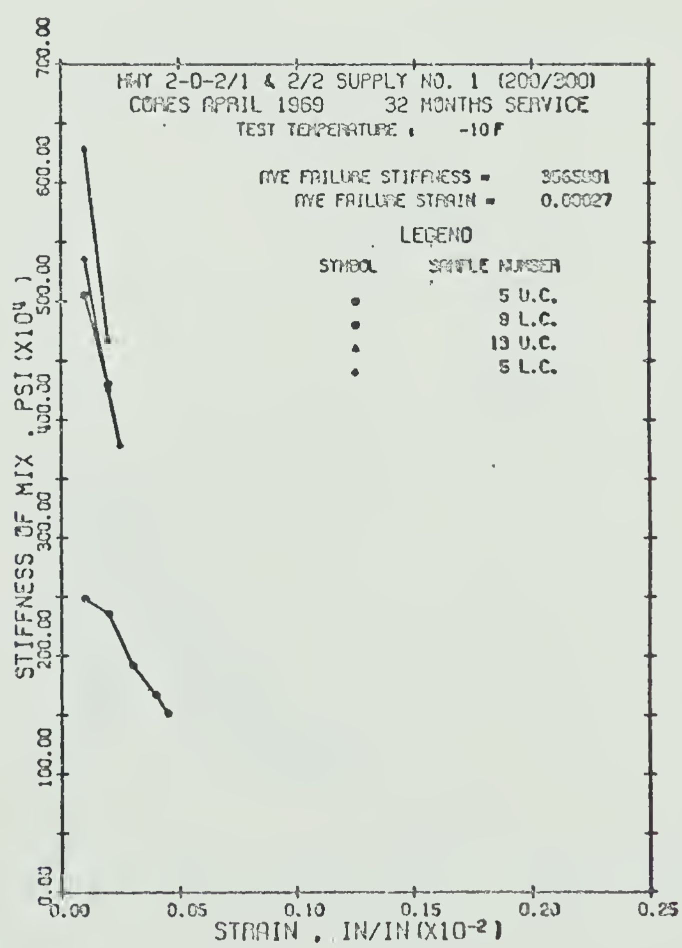


FIG. B14(d)

FIGURE B14: Supply No. 1 - 32 Months Service

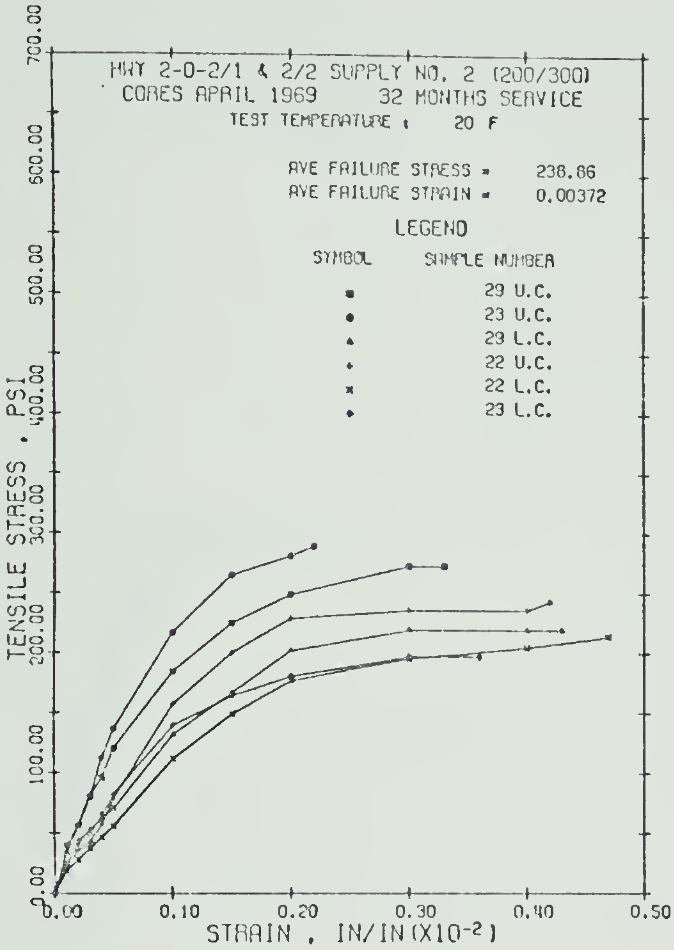


FIG. B15(a)

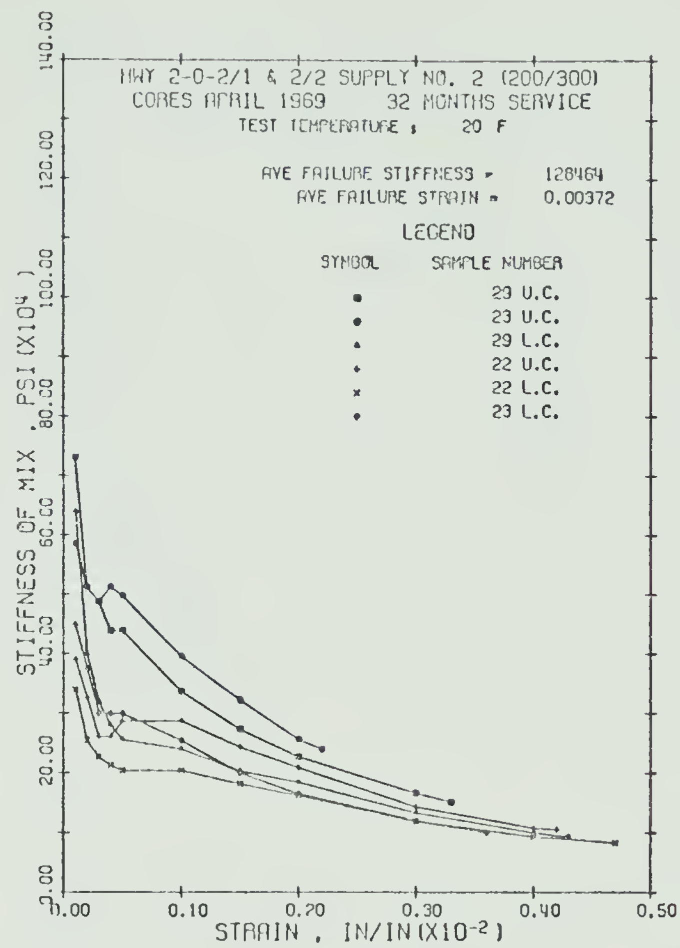


FIG. B15(b)

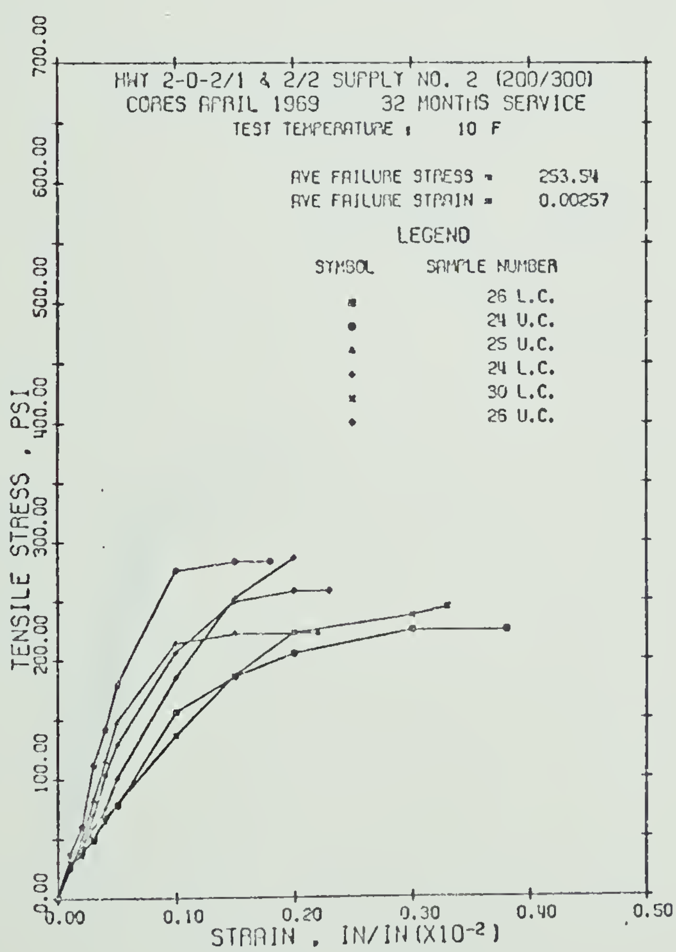


FIG. B15(c)

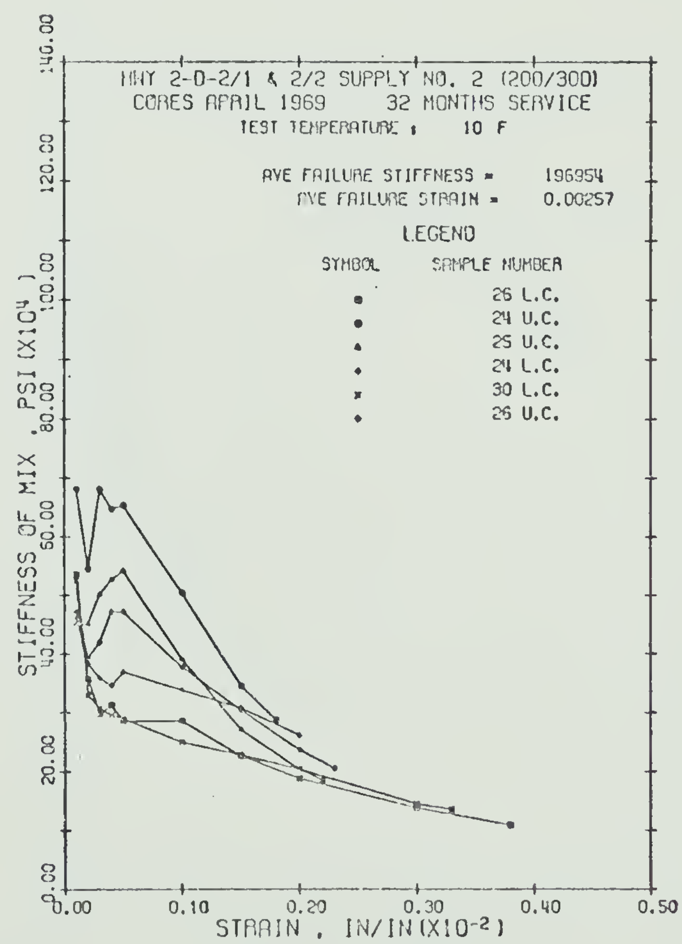


FIG. B15(d)

FIGURE B15: Supply No. 2 - 32 Months Service

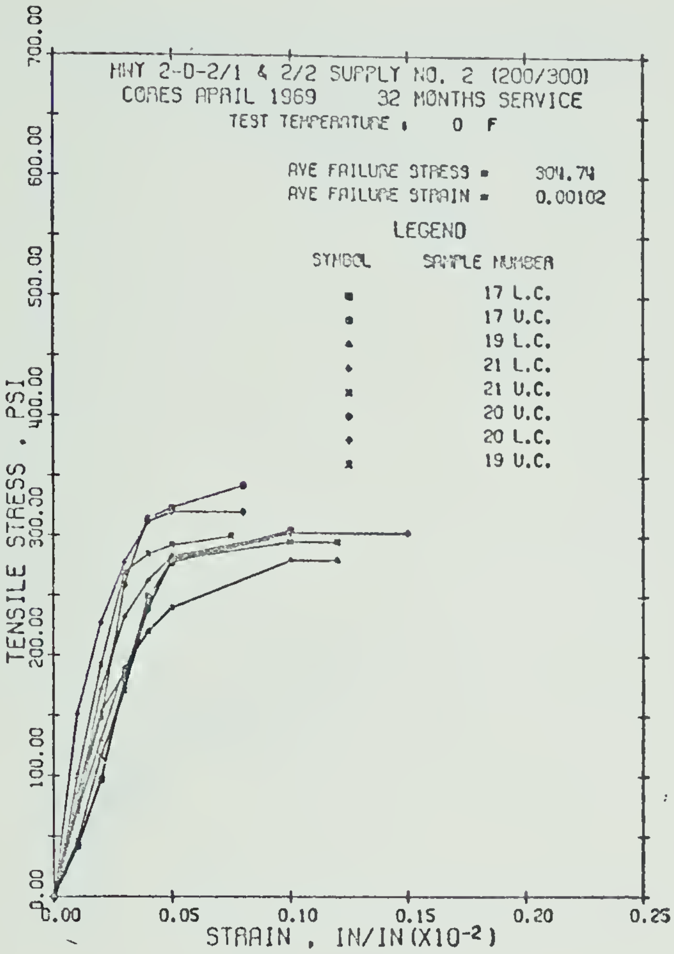


FIG. B16(a)

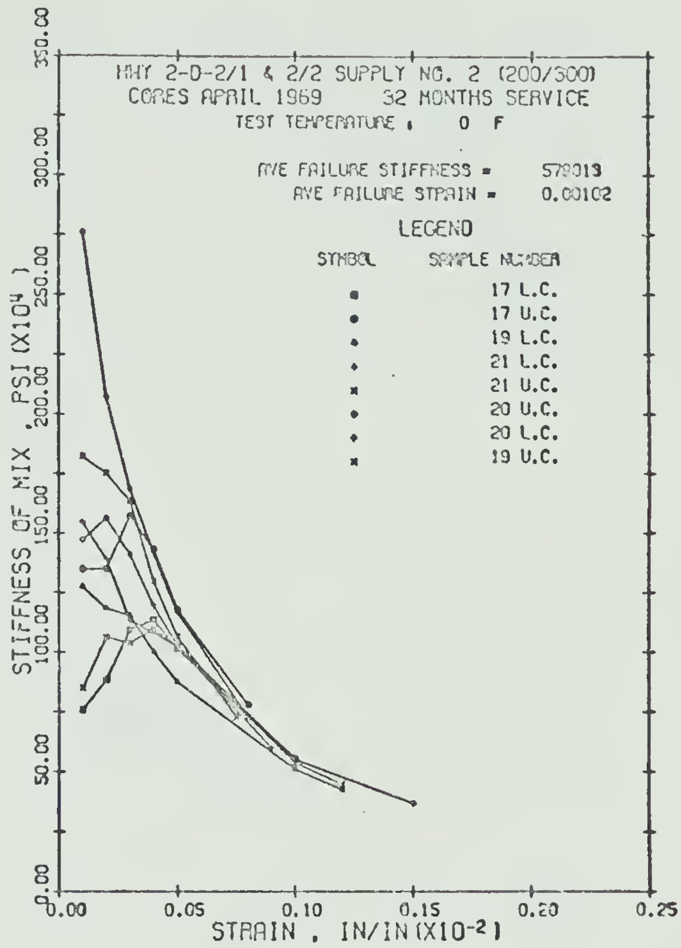


FIG. B16(b)

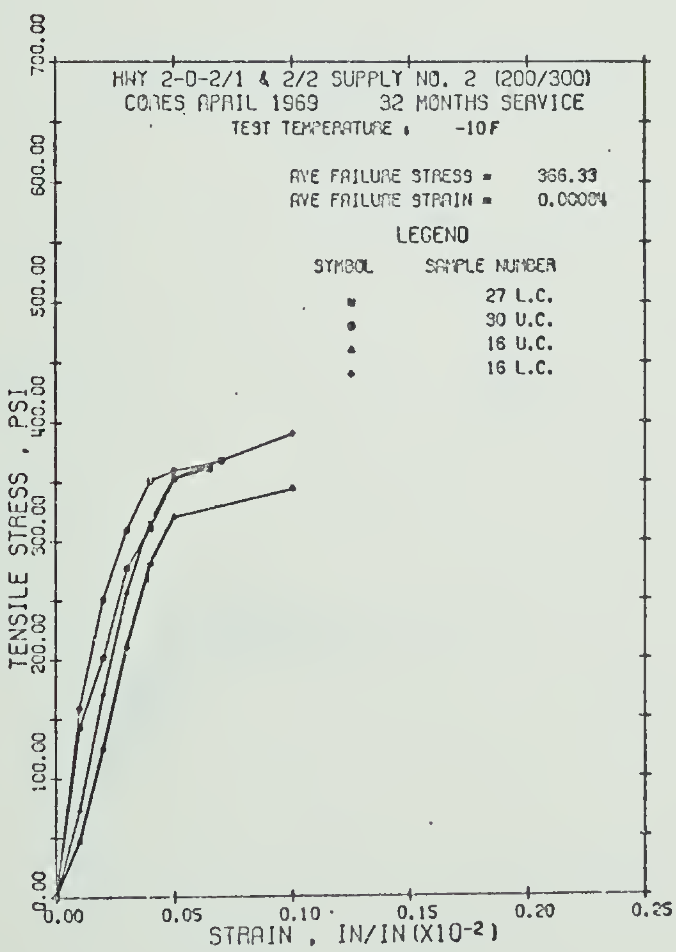


FIG. B16(c)

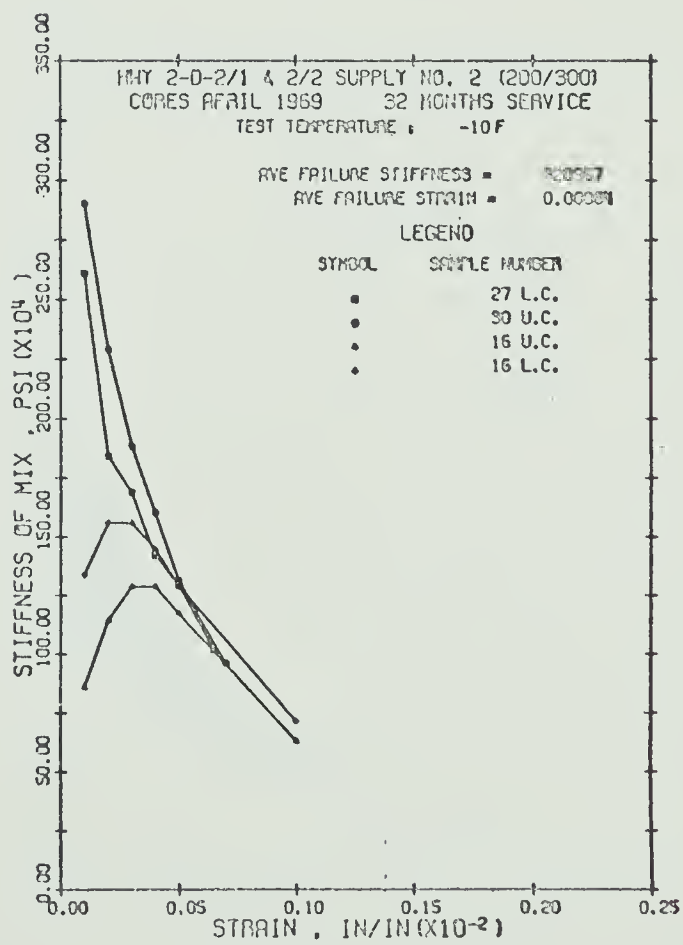


FIG. B16(d)

FIGURE B16: Supply No. 2 - 32 Months Service

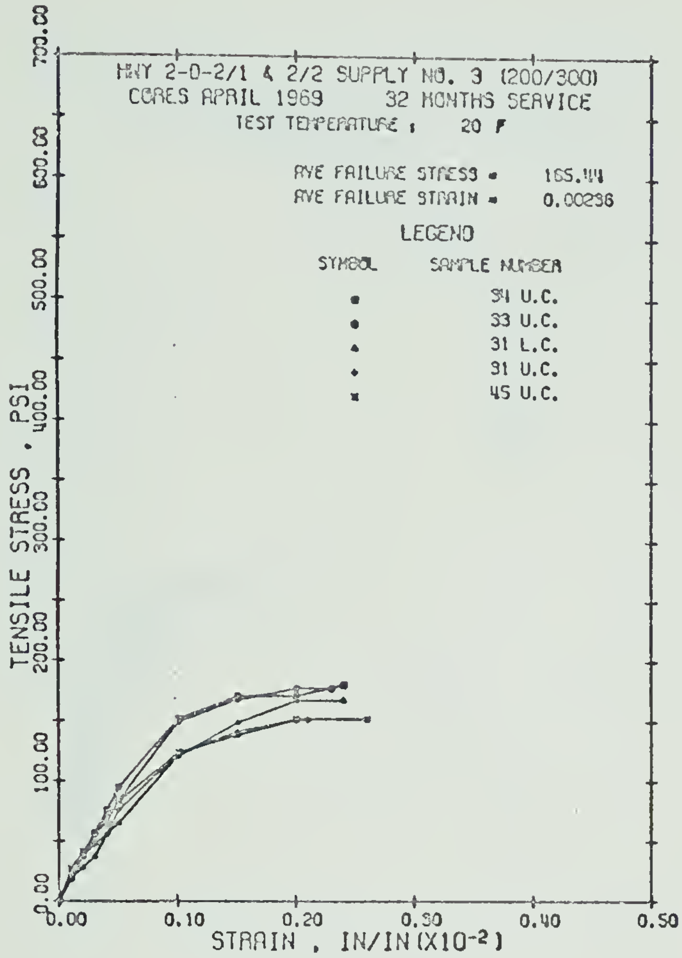


FIG. B17(a)

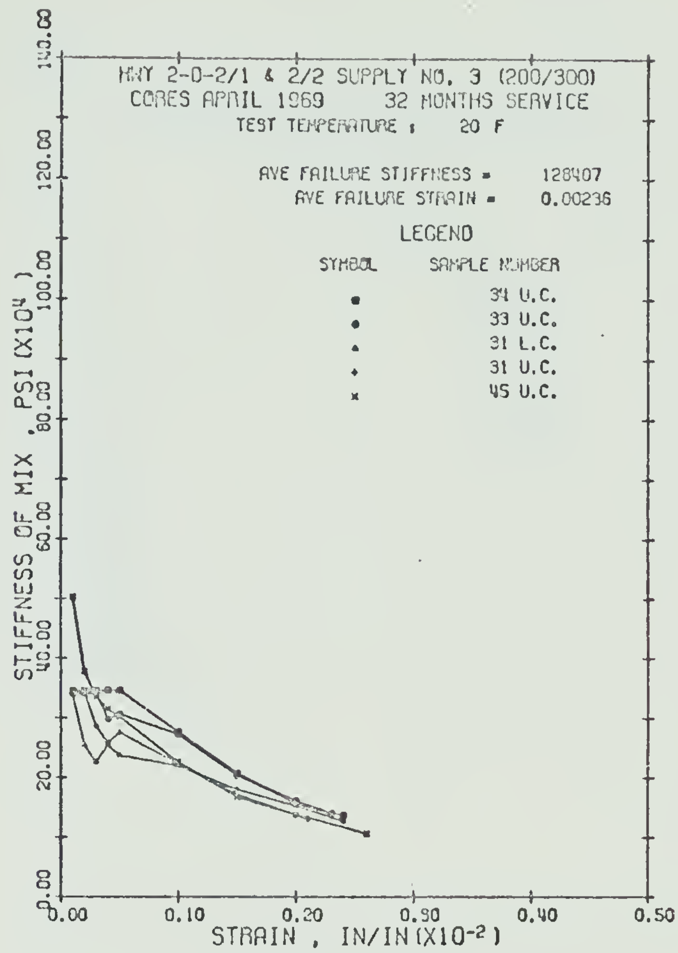


FIG. B17(b)

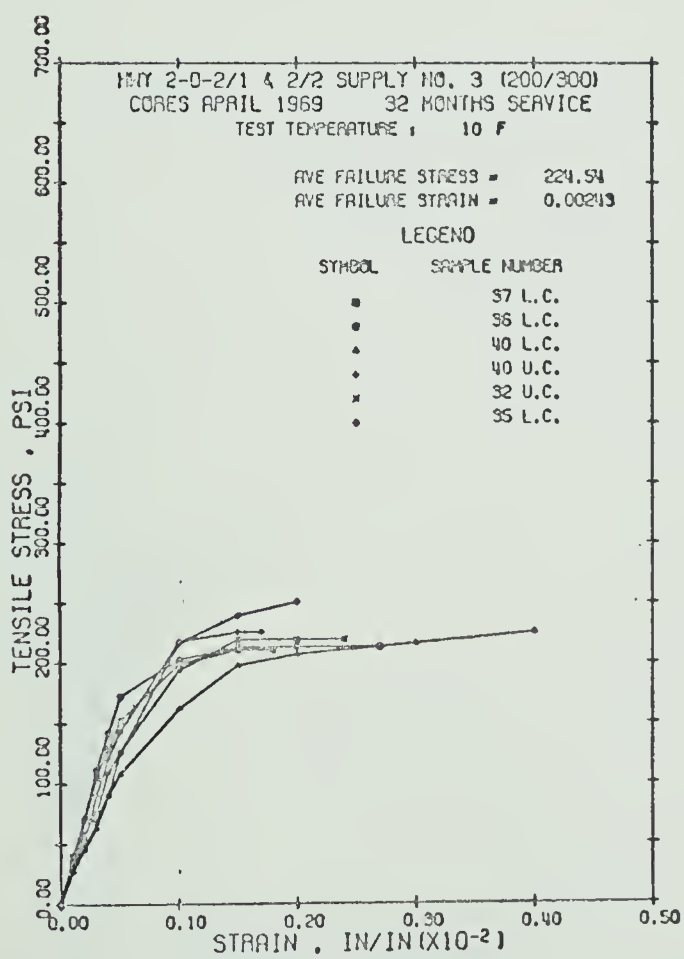


FIG. B17(c)

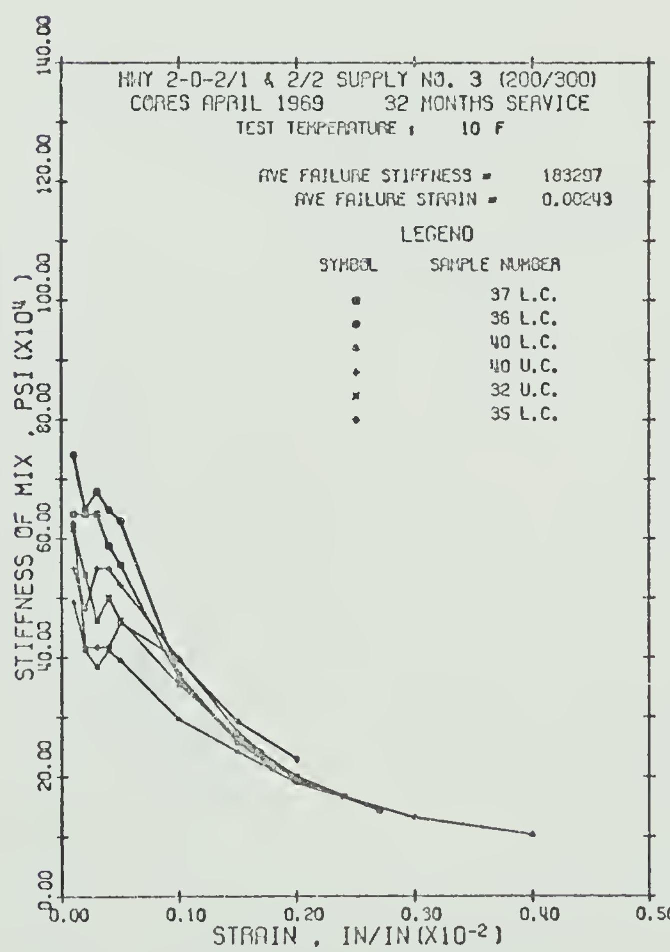


FIG. B17(d)

FIGURE B17: Supply No. 3 - 32 Months Service

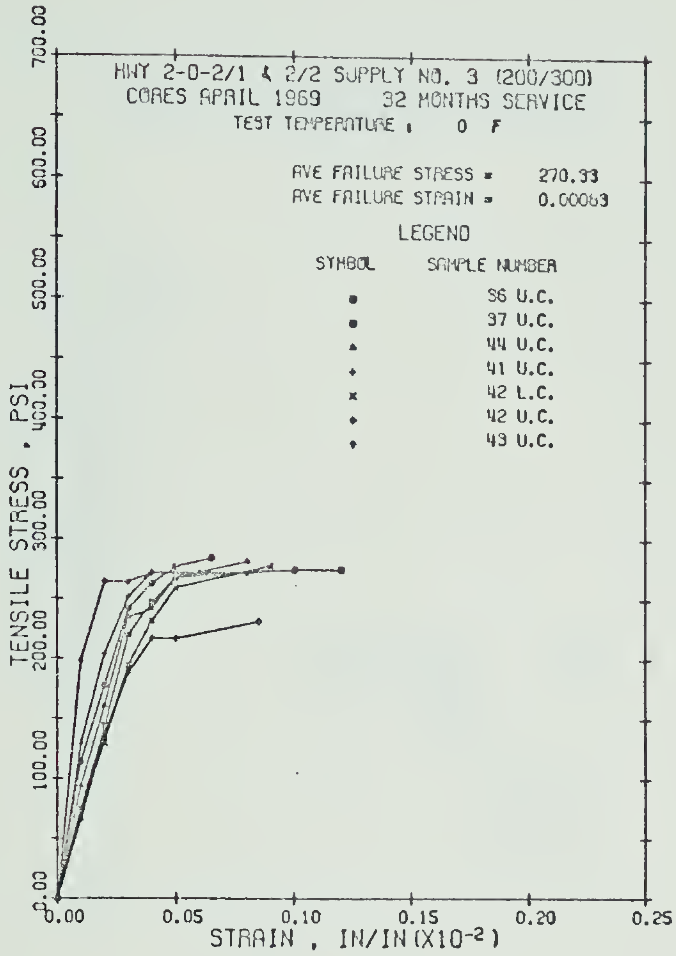


FIG. B18(a)

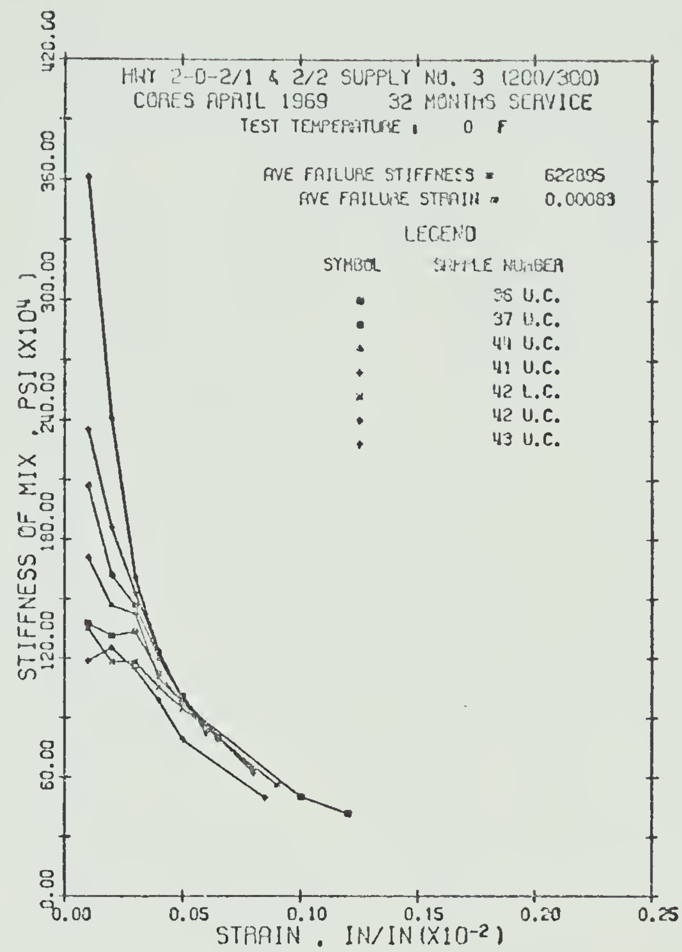


FIG. B18(b)

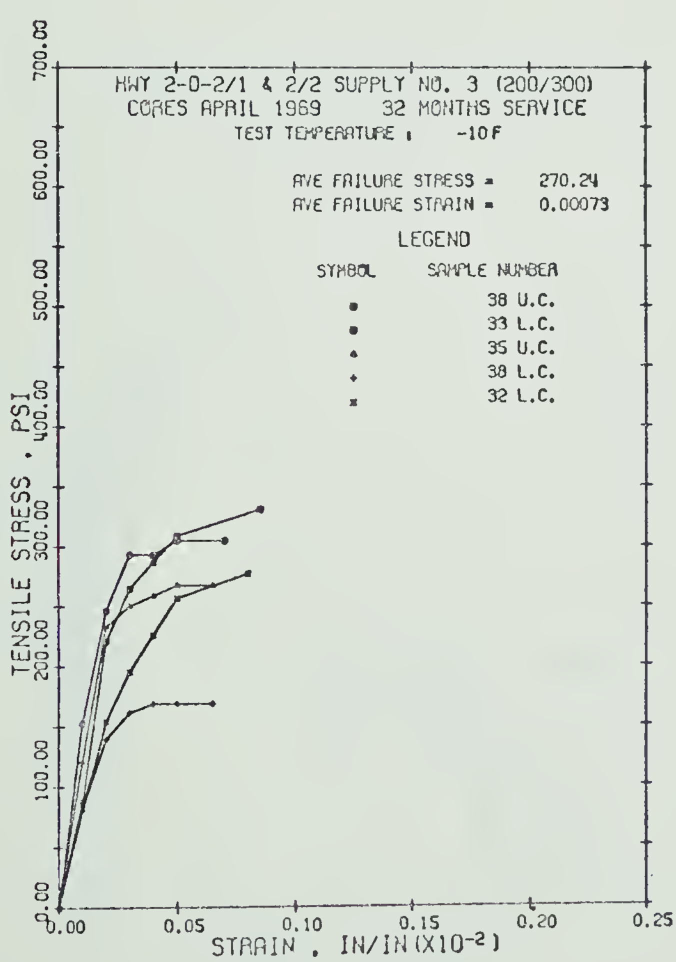


FIG. B18(c)

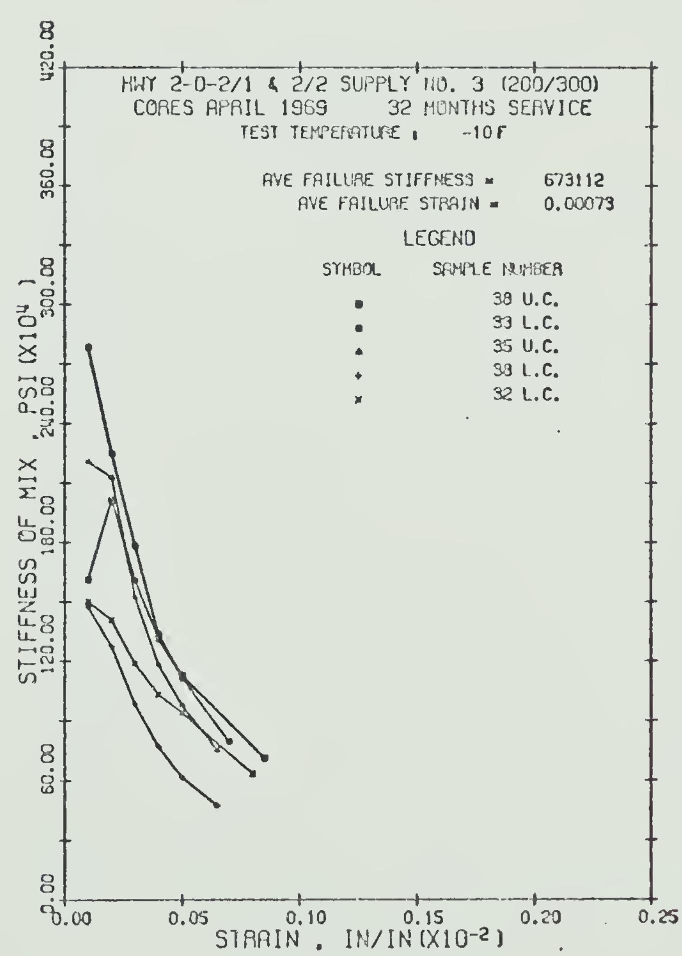


FIG. B18(d)

FIGURE B18: Supply No. 3 - 32 Months Service

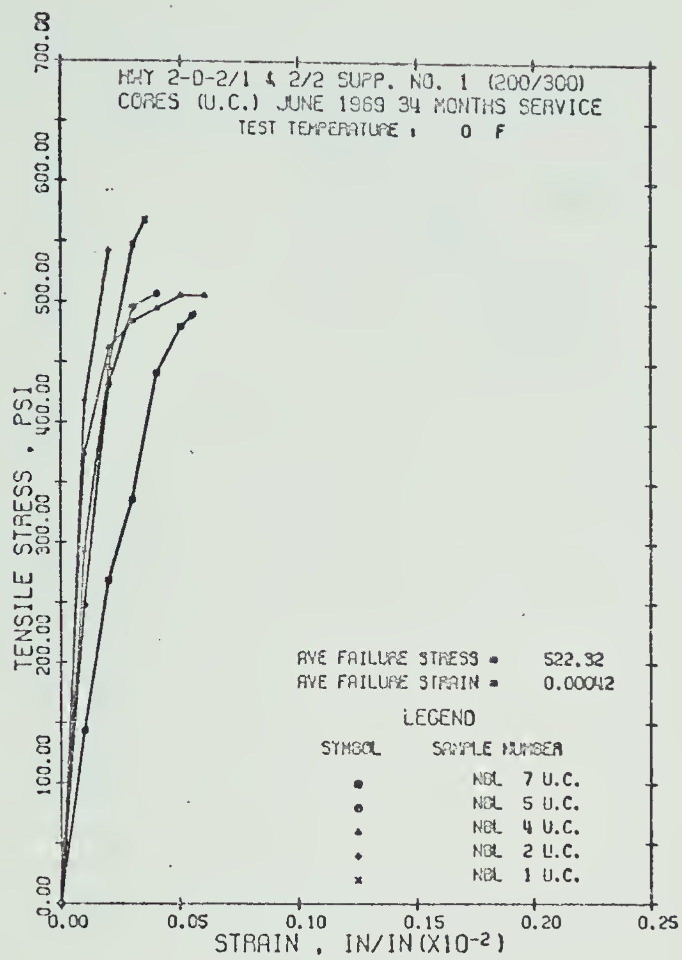


FIG. B19(a)

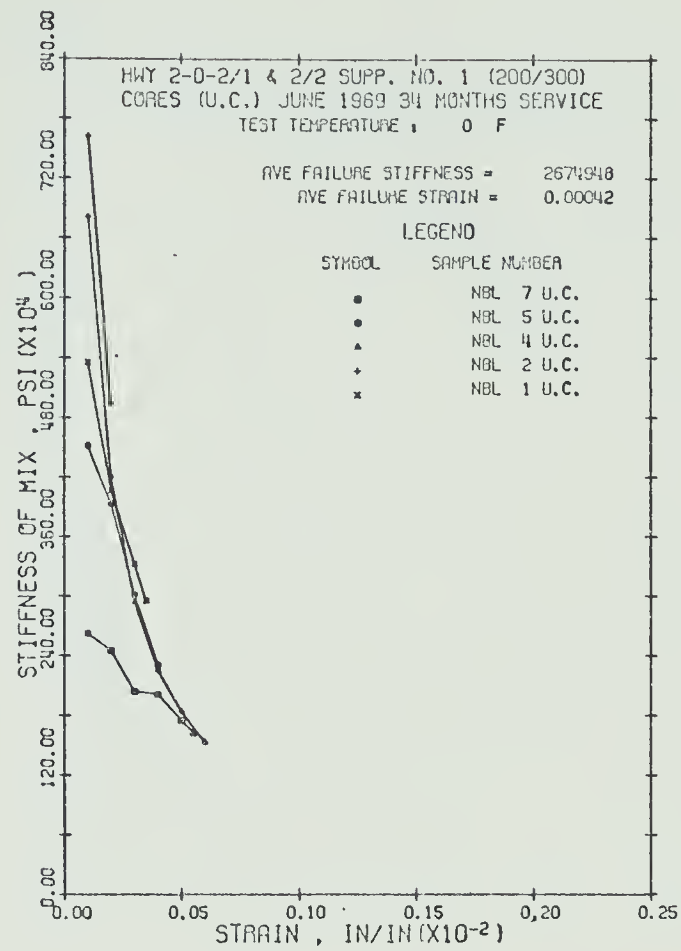


FIG. B19(b)

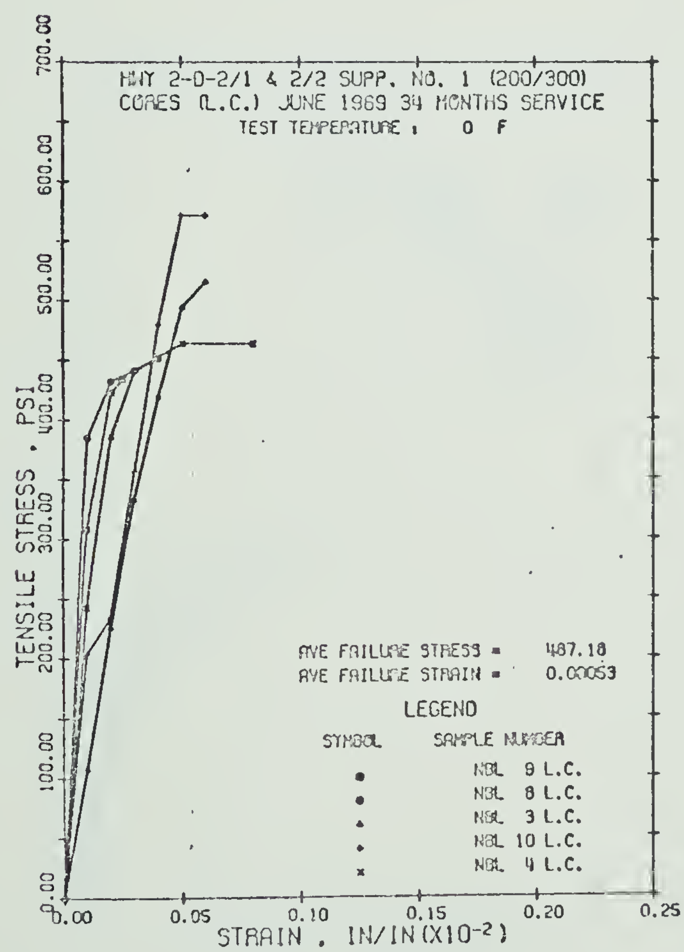


FIG. B19(c)

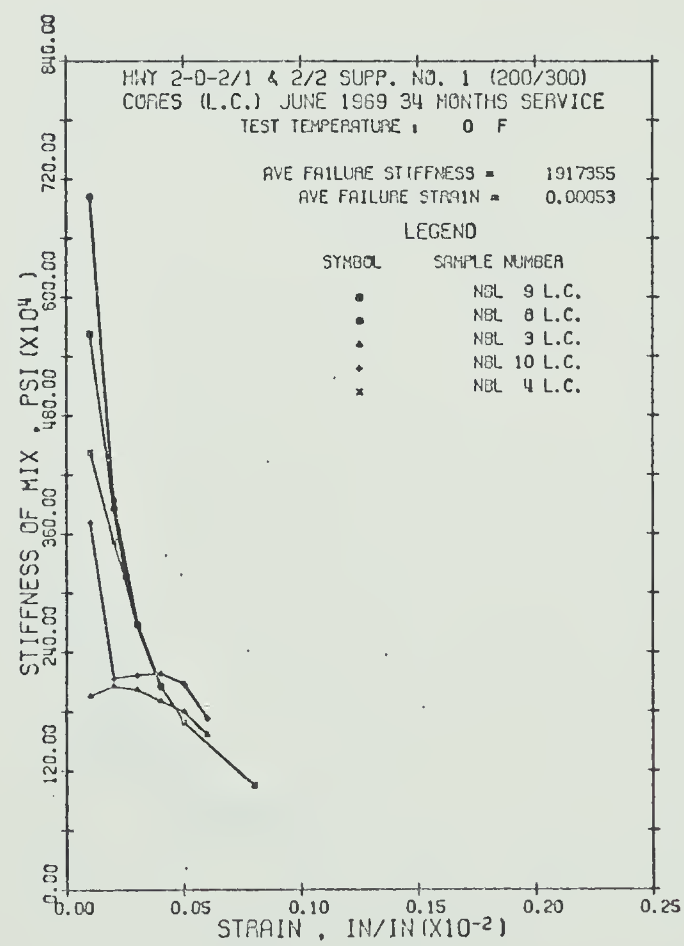


FIG. B19(d)

FIGURE B19: Supply No. 1 - 34 Months Service

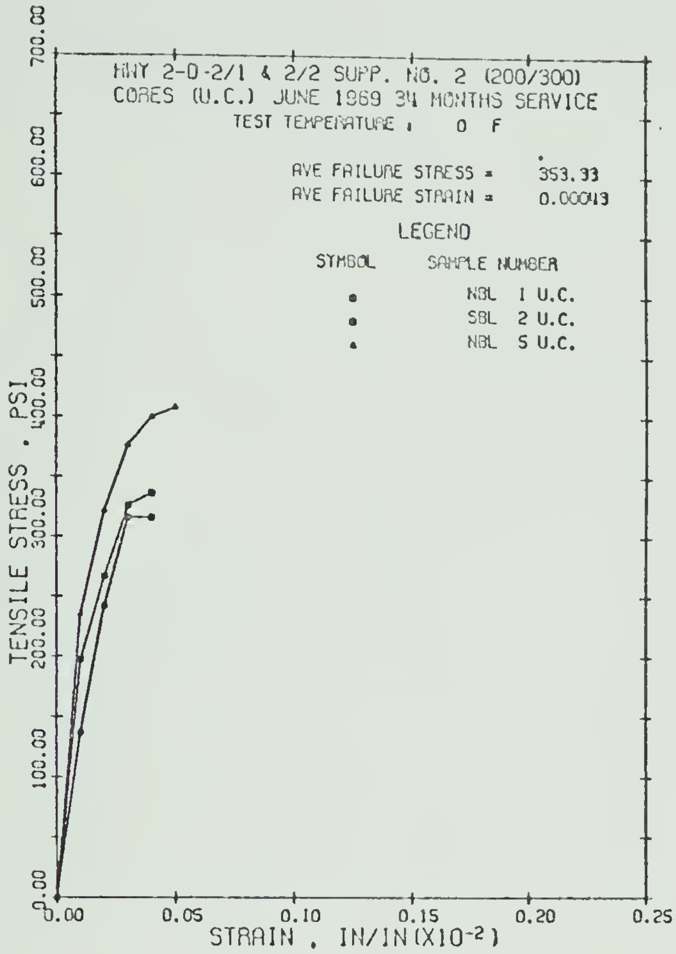


FIG. B20(a)

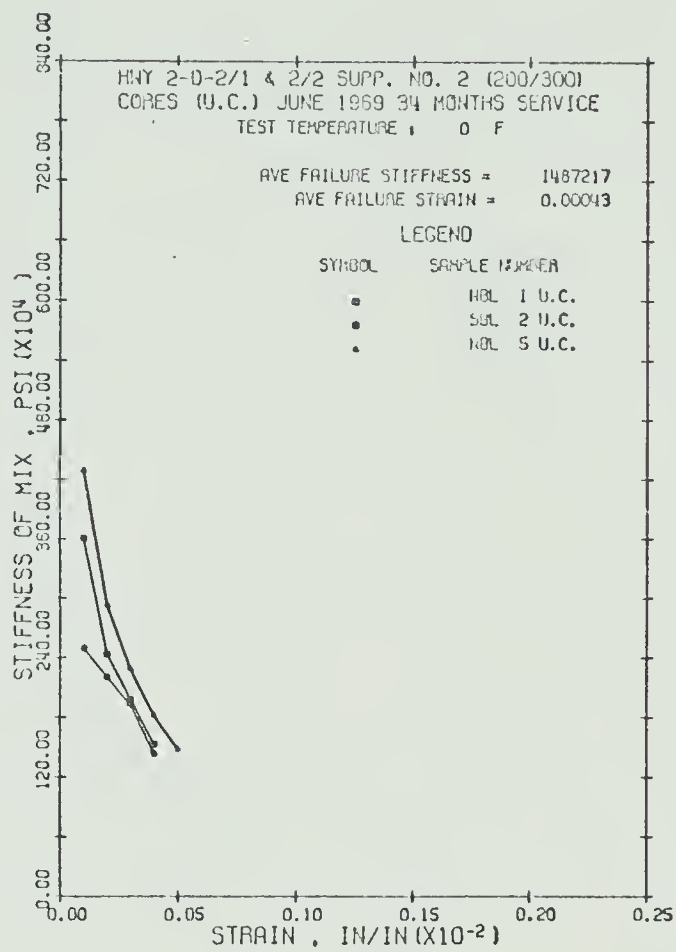


FIG. B20(b)

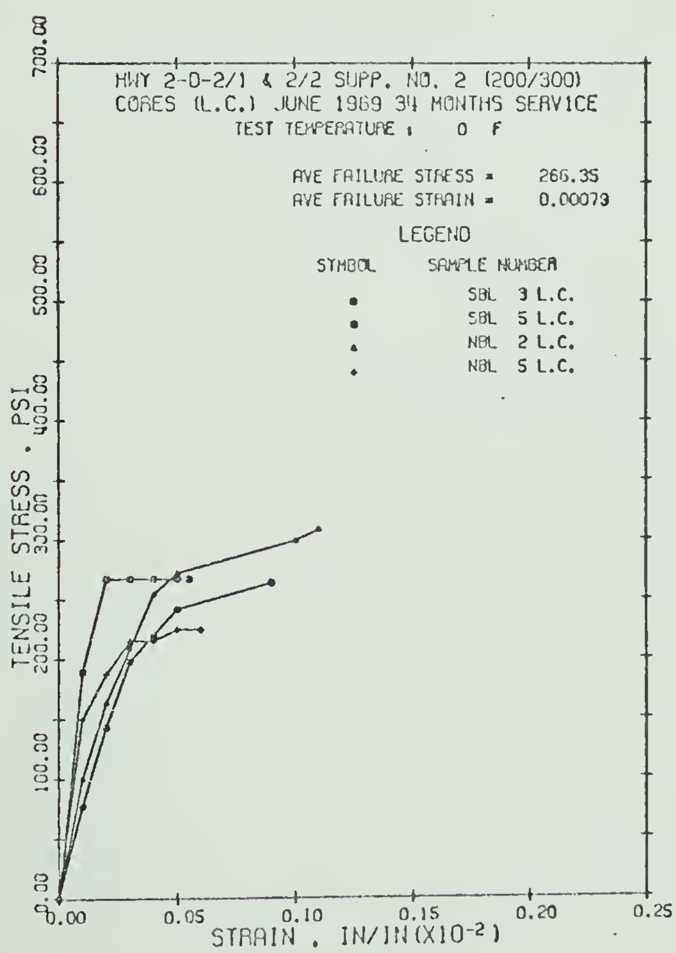


FIG. B20(c)

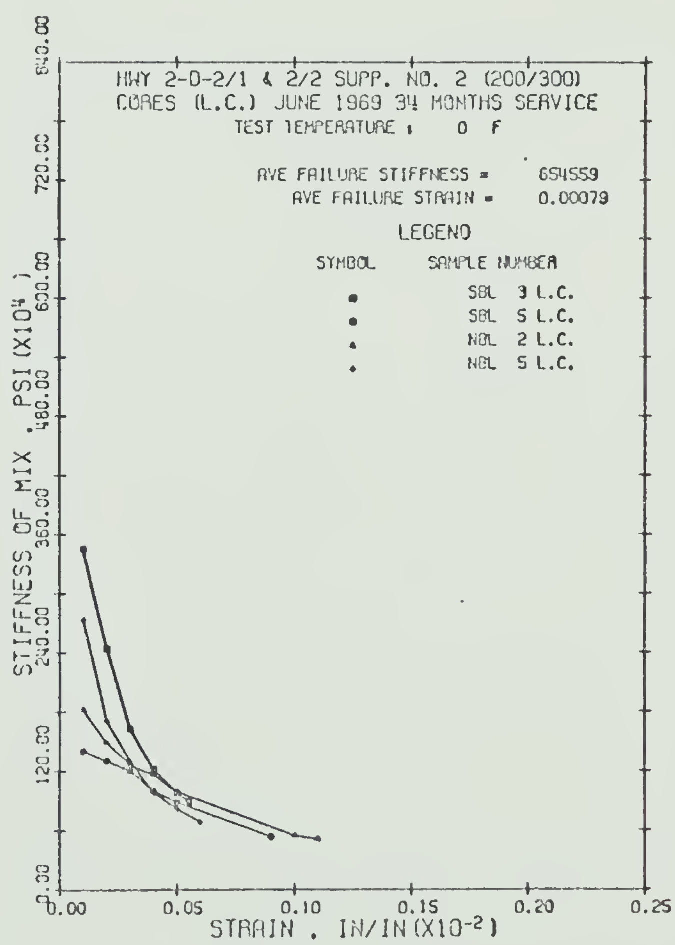


FIG. B20(d)

FIGURE B20: Supply No. 2 - 34 Months Service

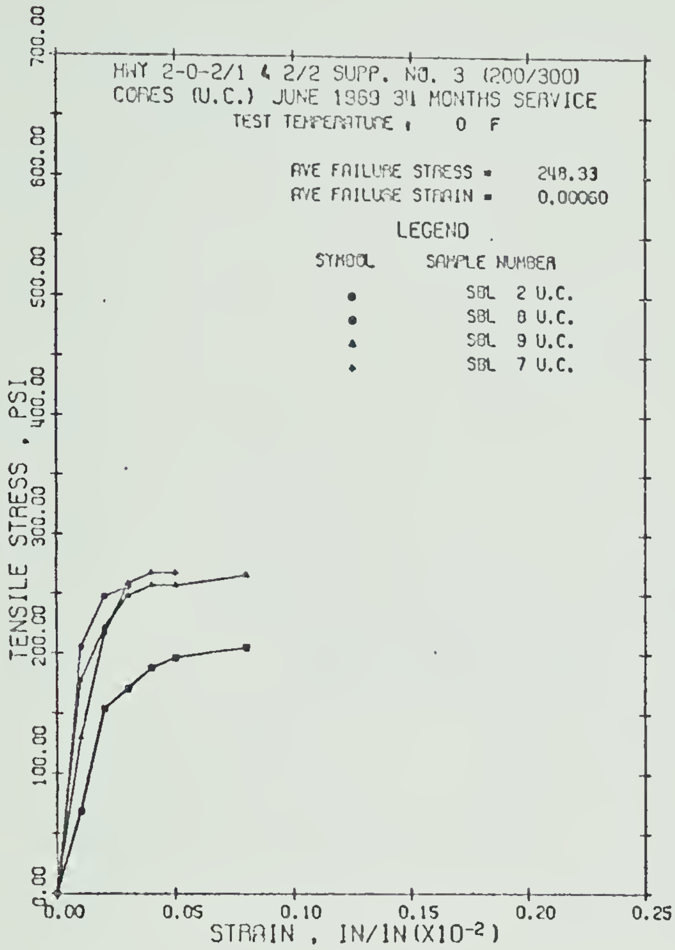


FIG. B21(a)

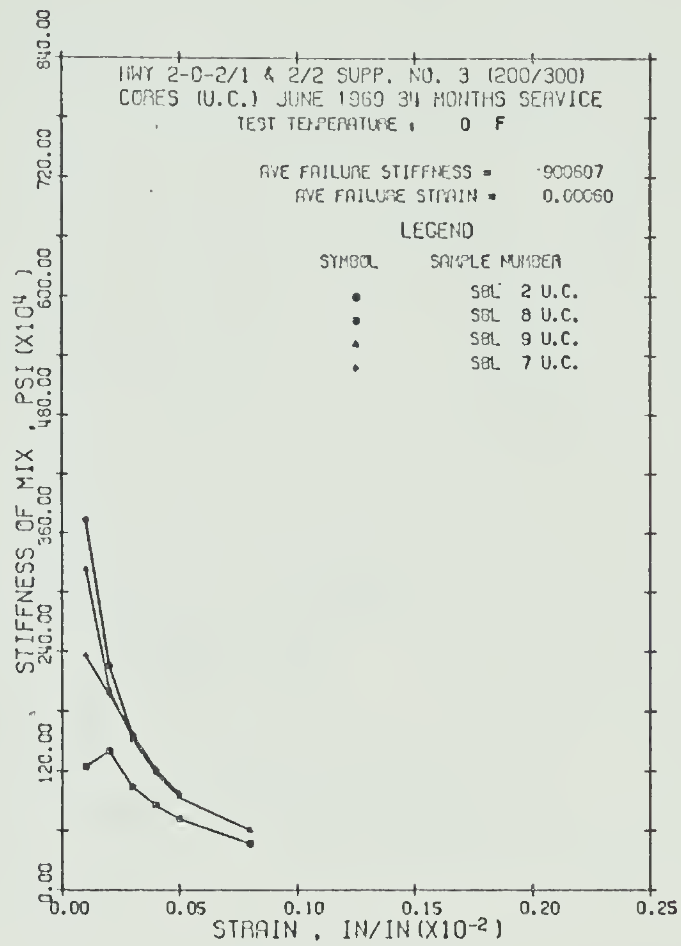


FIG. B21(b)

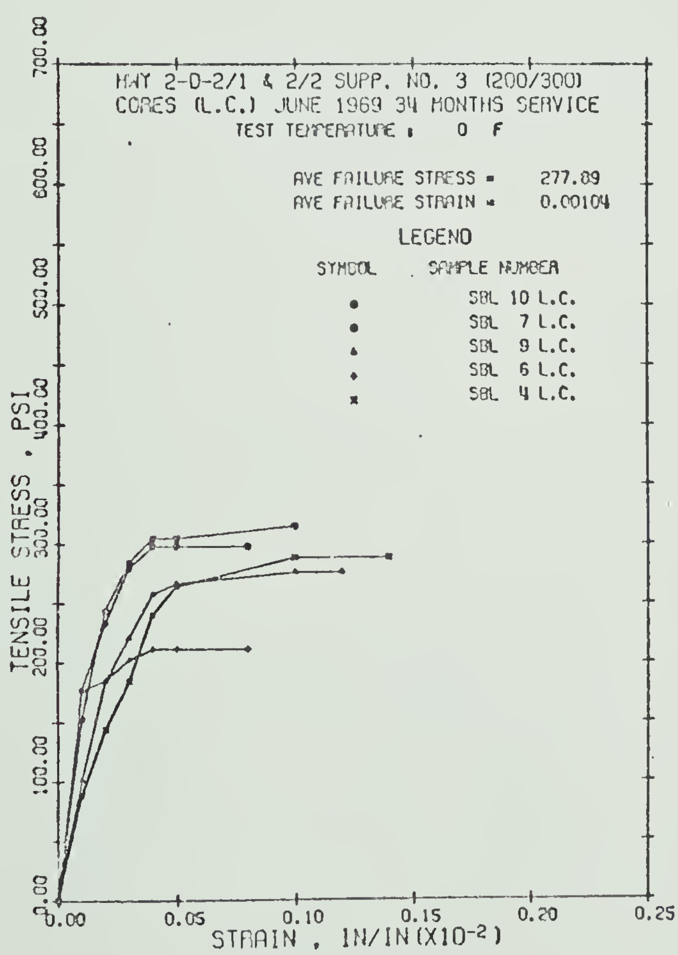


FIG. B21(c)

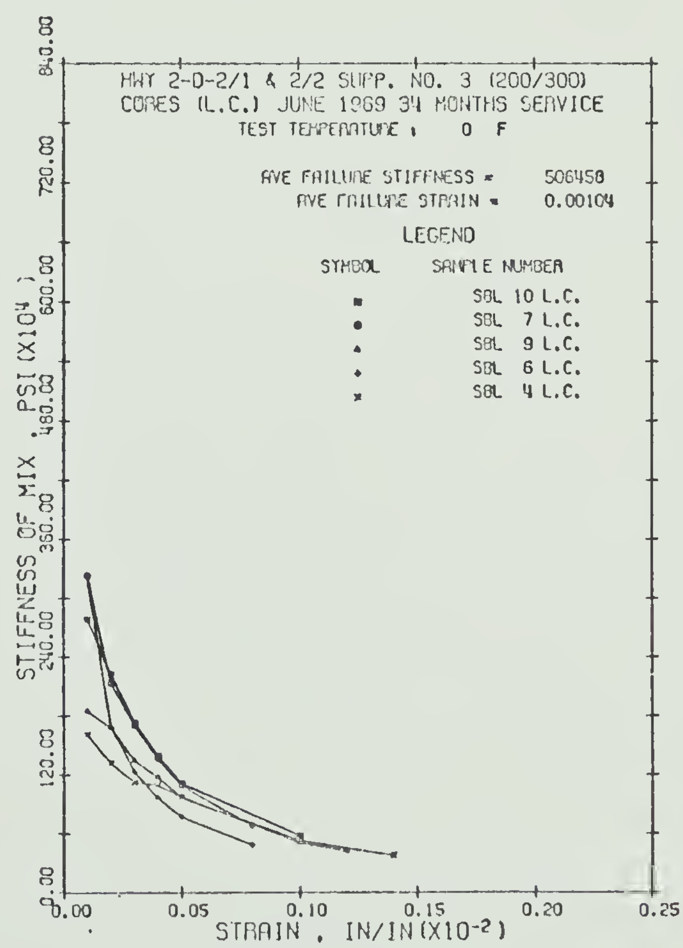


FIG. B21(d)

FIGURE B21: Supply No. 3 - 34 Months Service

A P P E N D I X   C

COMPUTER PLOTS OF TENSILE STRESS VS. STRAIN

AND STIFFNESS OF MIX VS. STRAIN FOR

WATSONVILLE AGGREGATE

CALIFORNIA ASPHALT AND KNEADING COMPACTION METHOD

(ANDERSON, 1968)

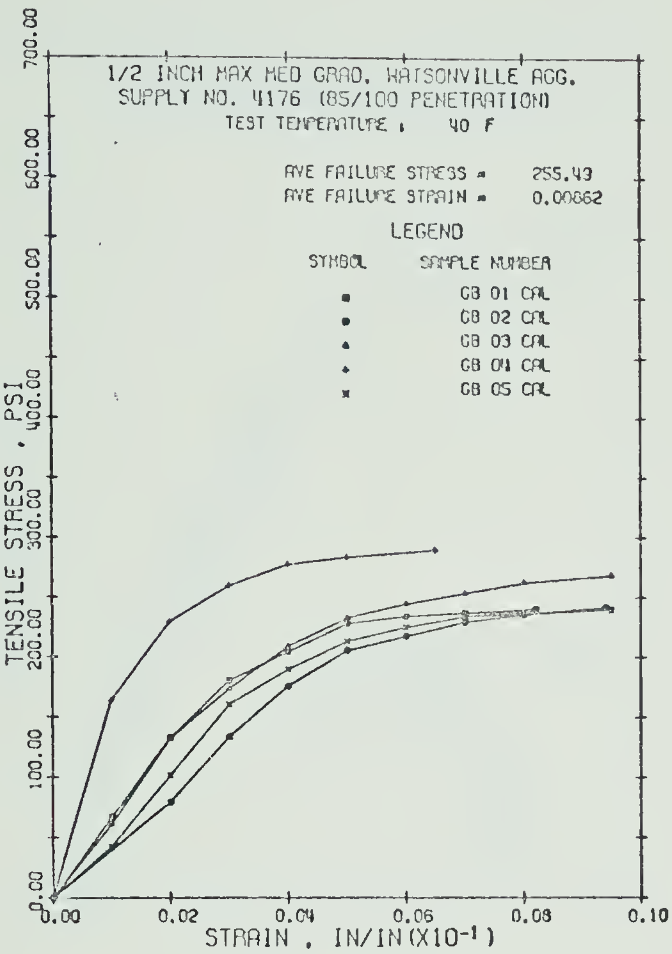


FIG. C1(a)

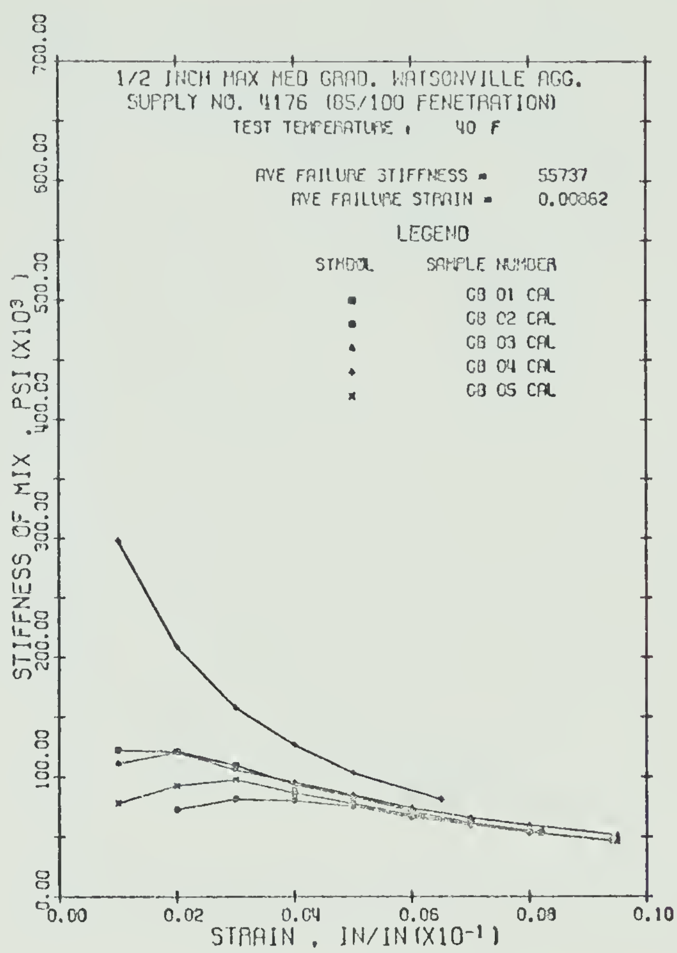


FIG. C1(b)

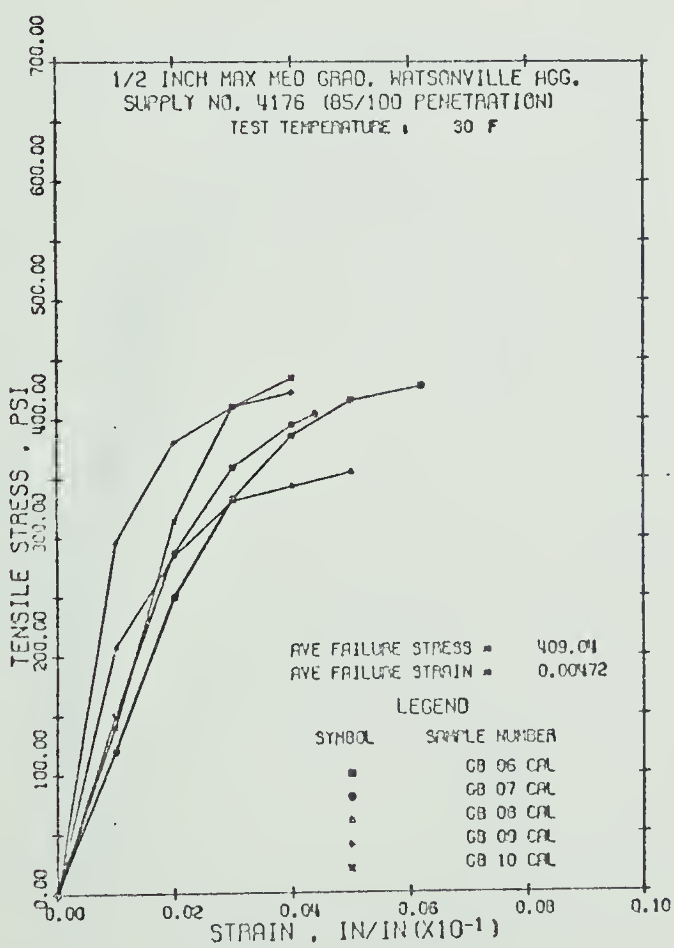


FIG. C1(c)

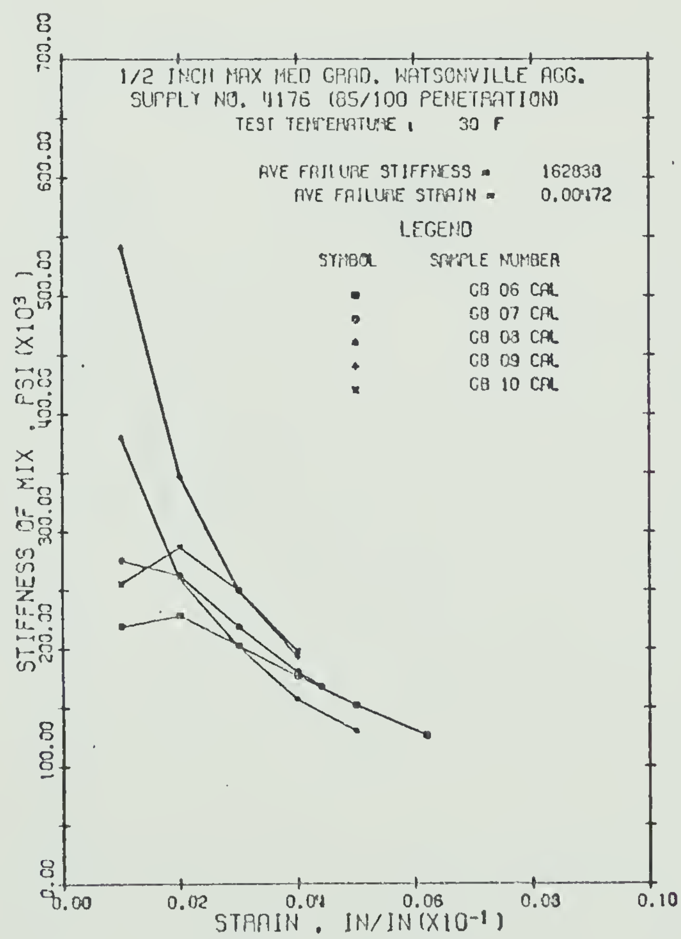


FIG. C1(d)

FIGURE C1: Golden Bear (85/100 Penetration)

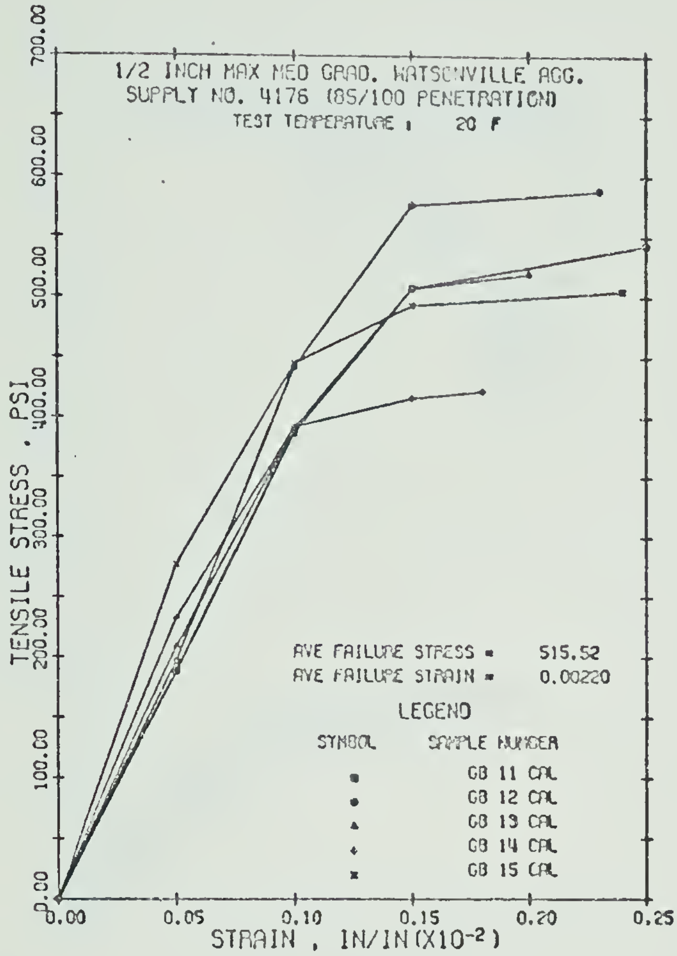


FIG. C2(a)

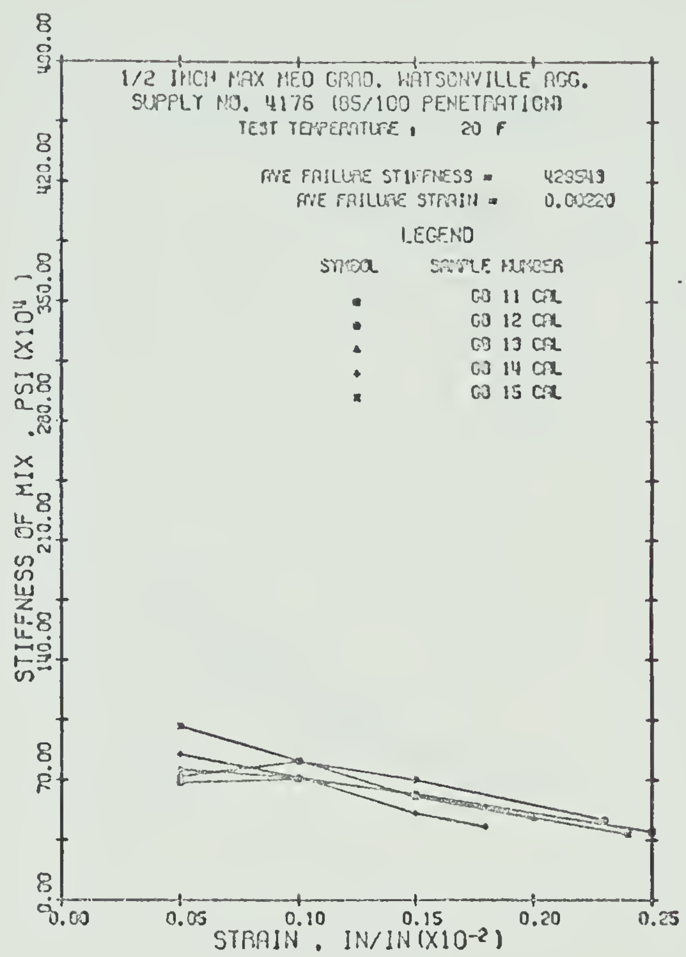


FIG. C2(b)

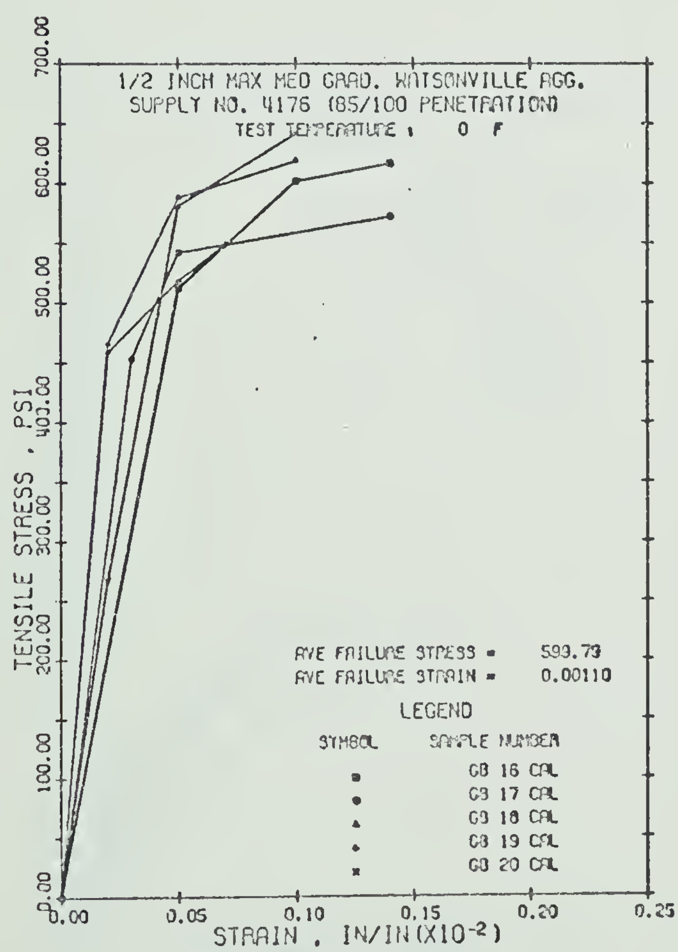


FIG. C2(c)

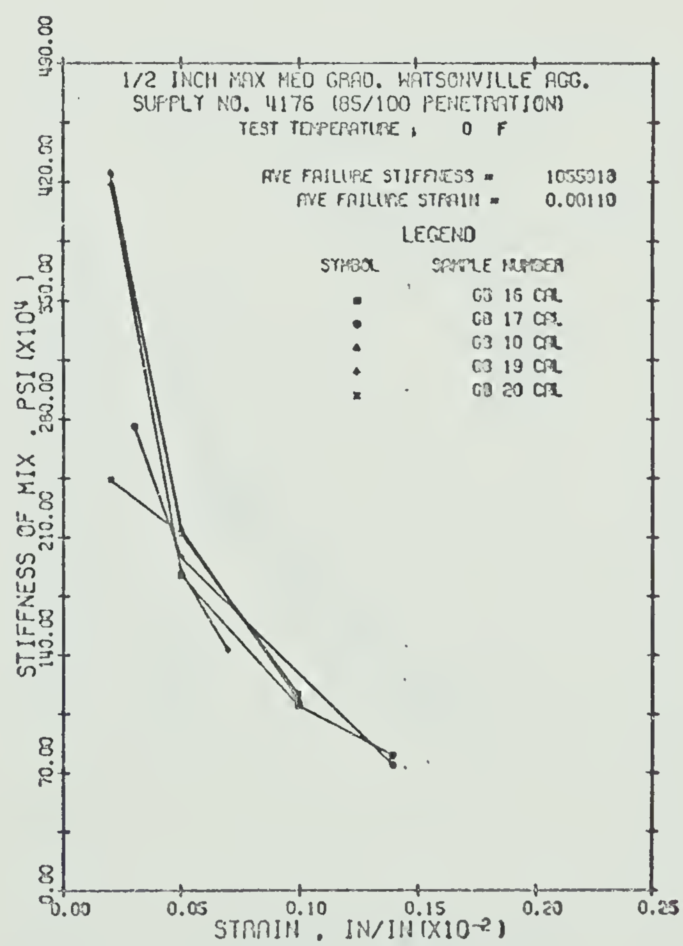


FIG. C2(d)

FIGURE C2: Golden Bear (85/100 Penetration)

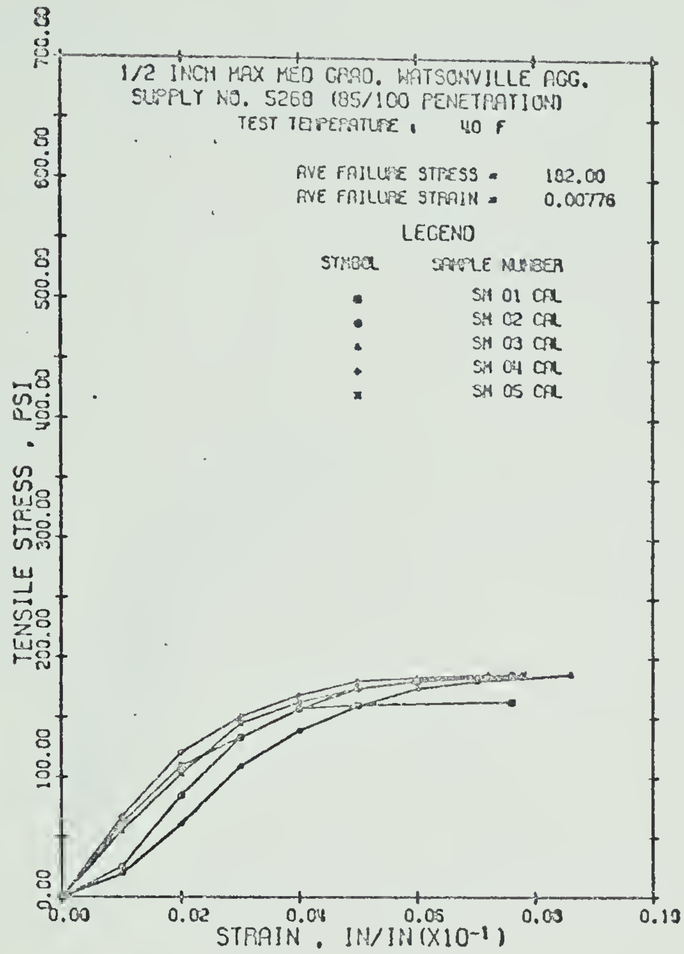


FIG. C3(a)

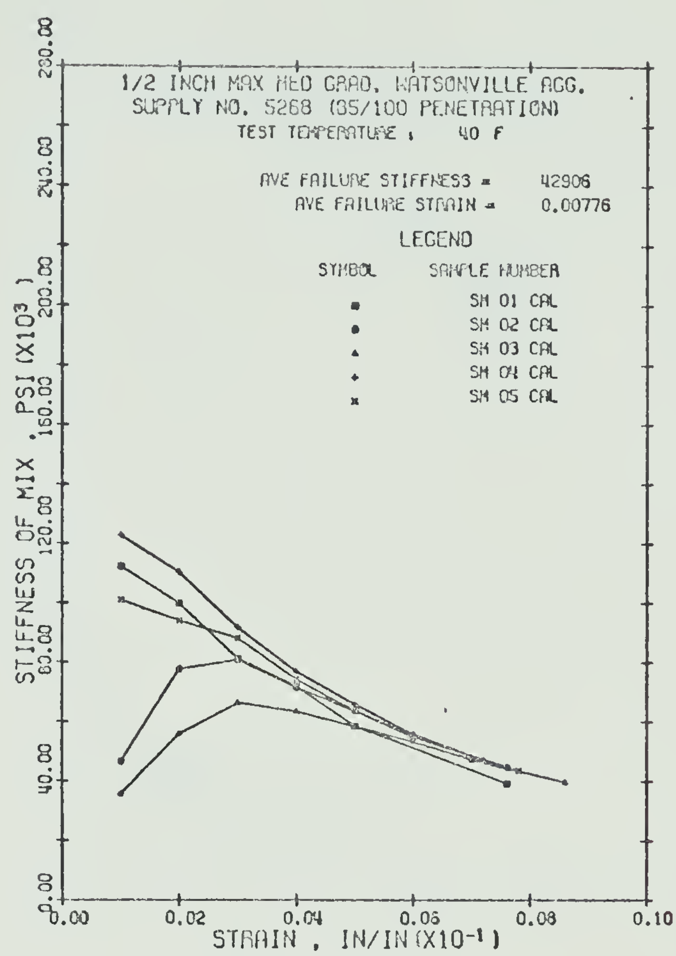


FIG. C3(b)

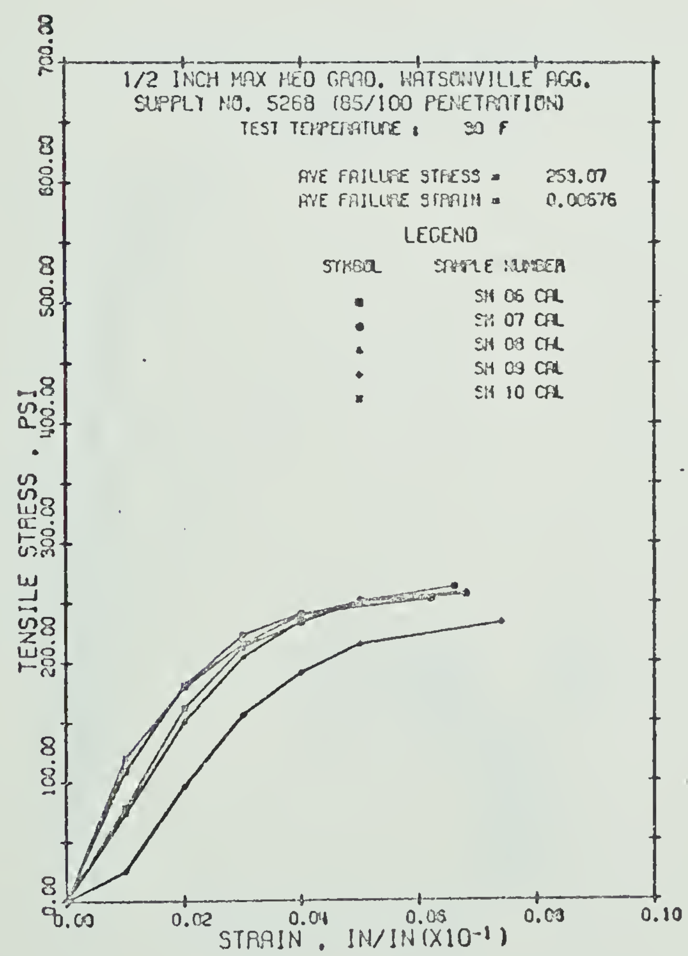


FIG. C3(c)

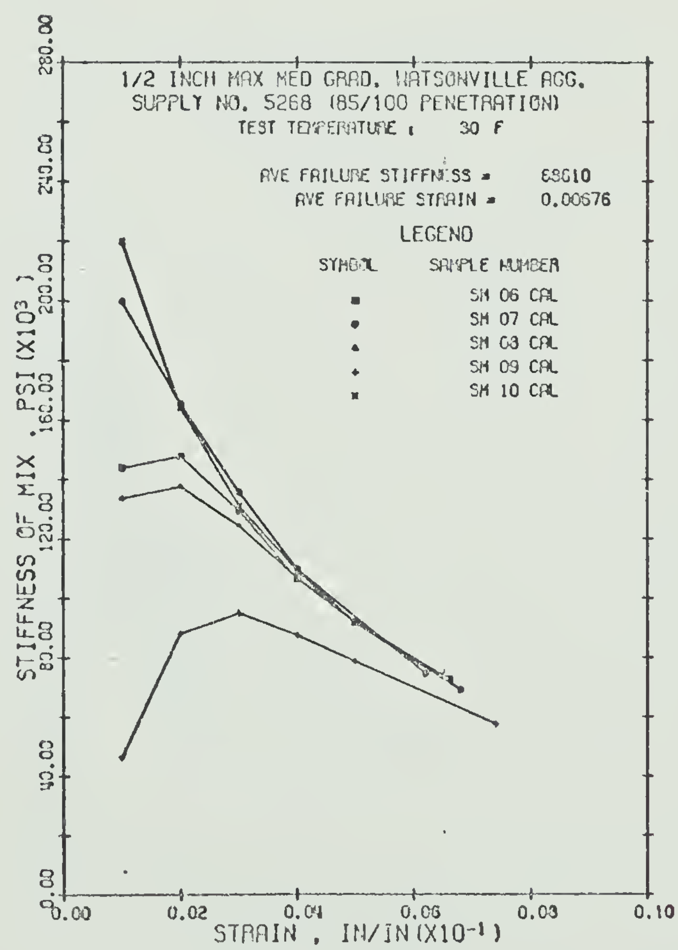


FIG. C3(d)

FIGURE C3: Santa Maria (85/100 Penetration)

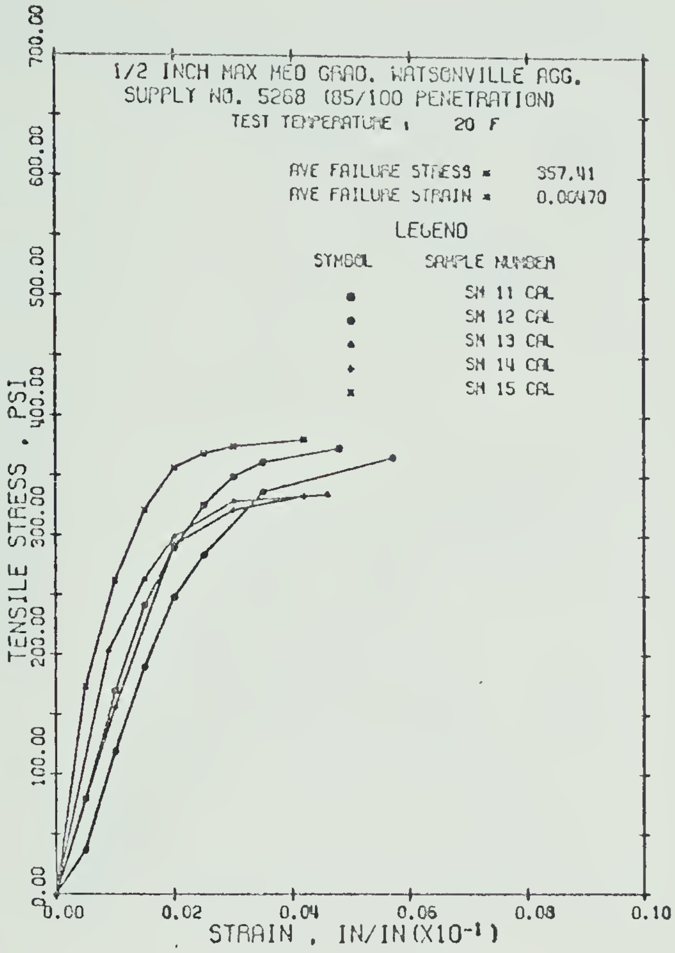


FIG. C4(a)

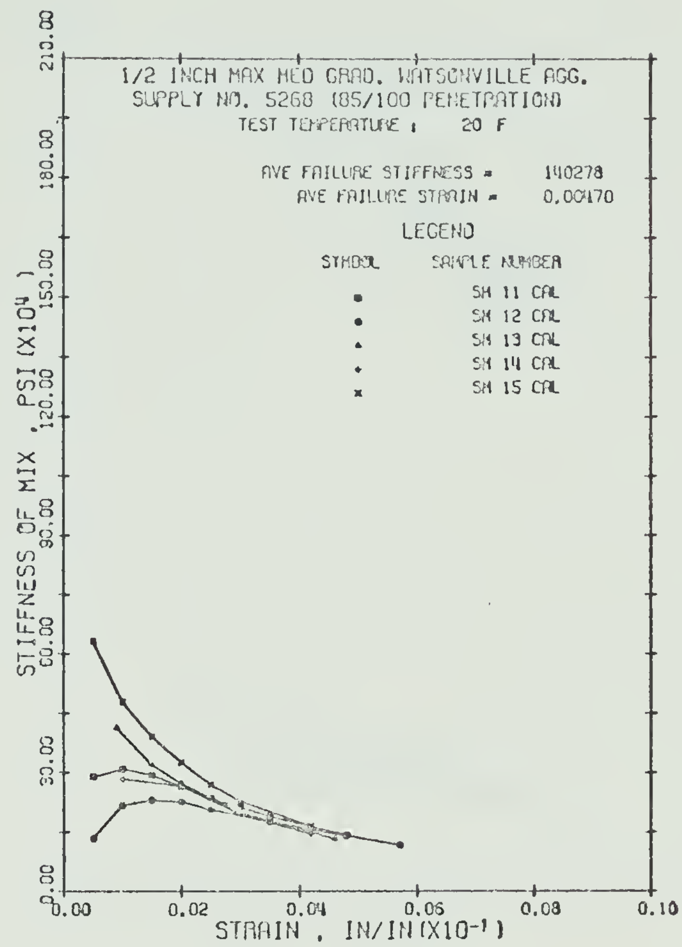


FIG. C4(b)

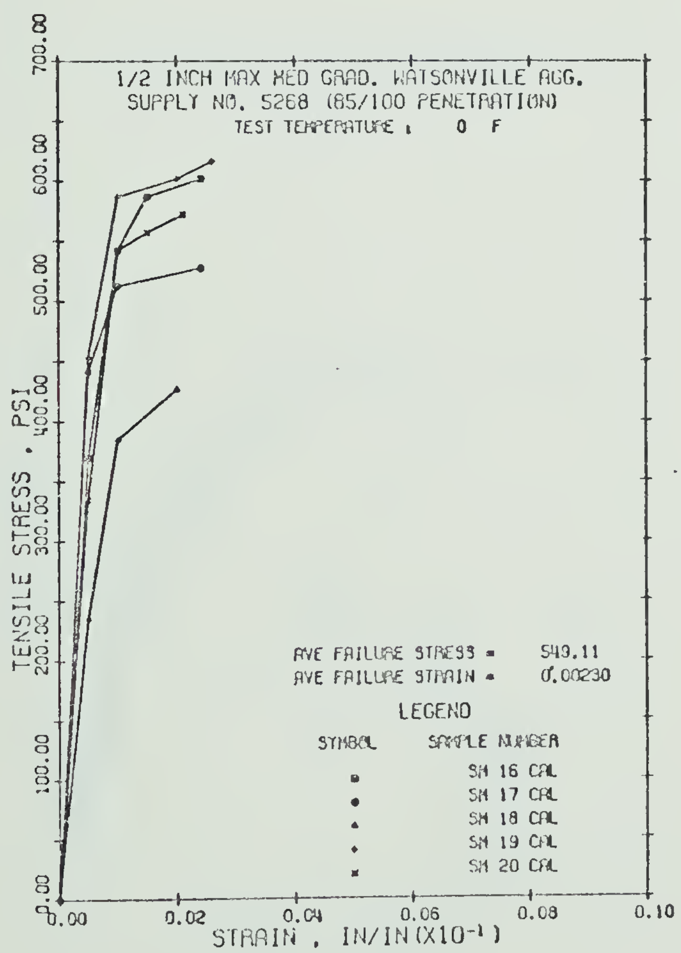


FIG. C4(c)

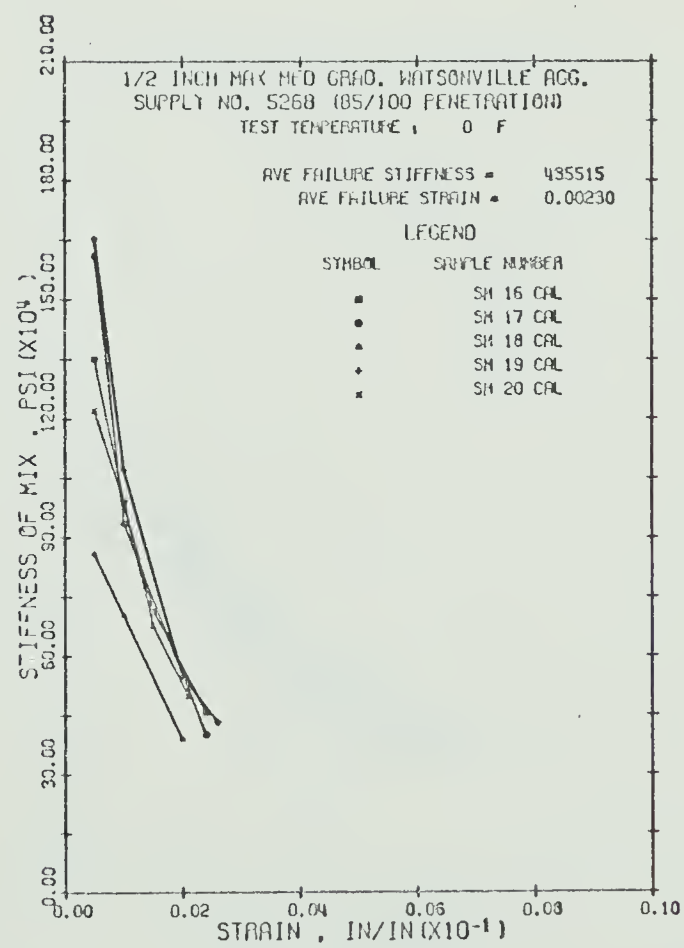


FIG. C4(d)

FIGURE C4: Santa Maria (85/100 Penetration)

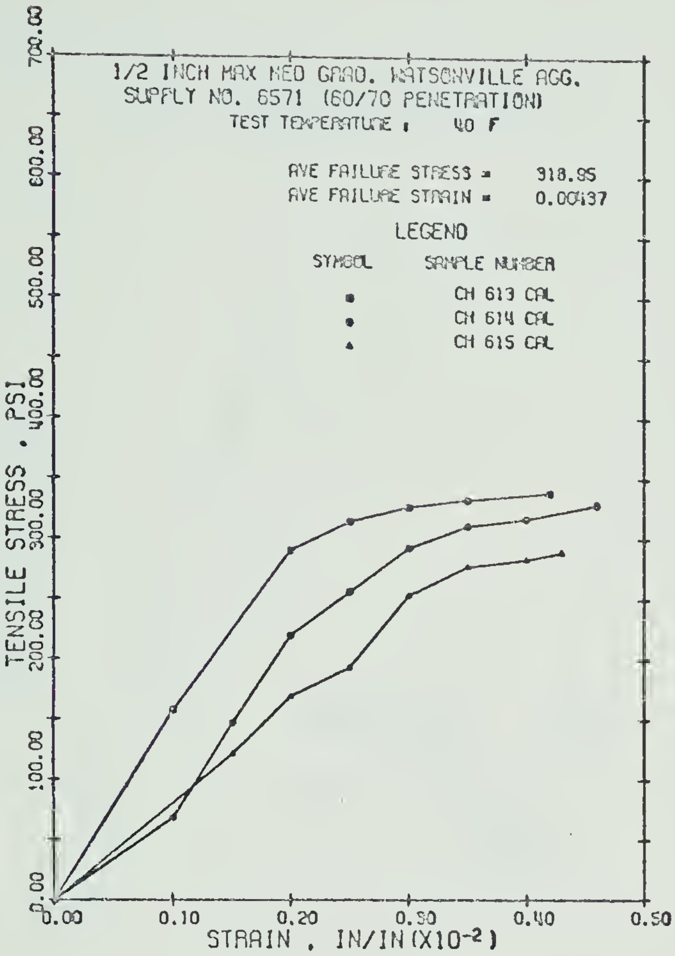


FIG. C5(a)

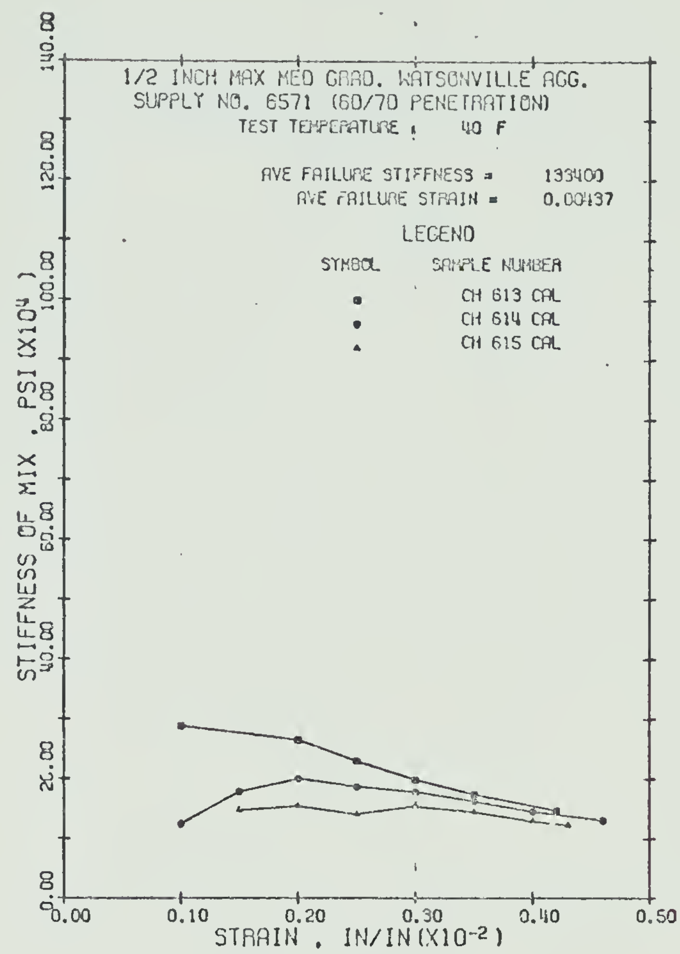


FIG. C5(b)

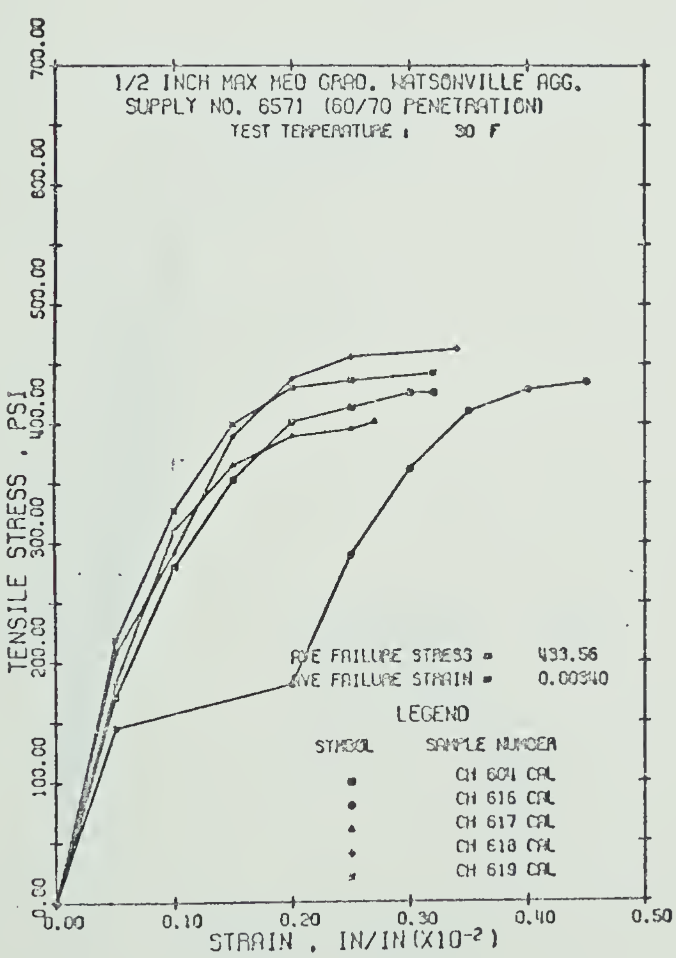


FIG. C5(c)

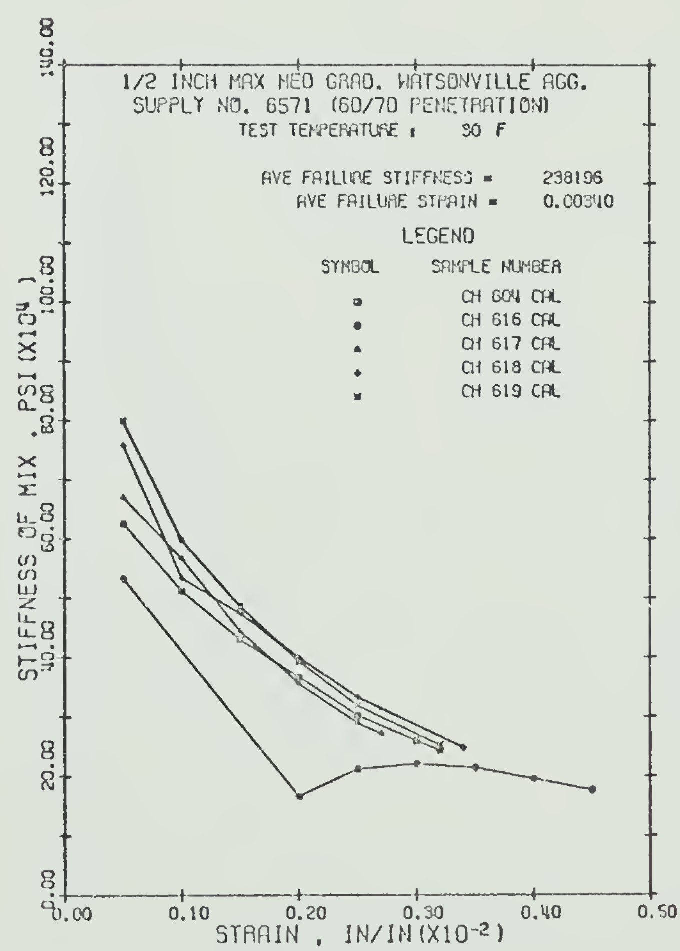


FIG. C5(d)

FIGURE C5: Chevron (60/70 Penetration)

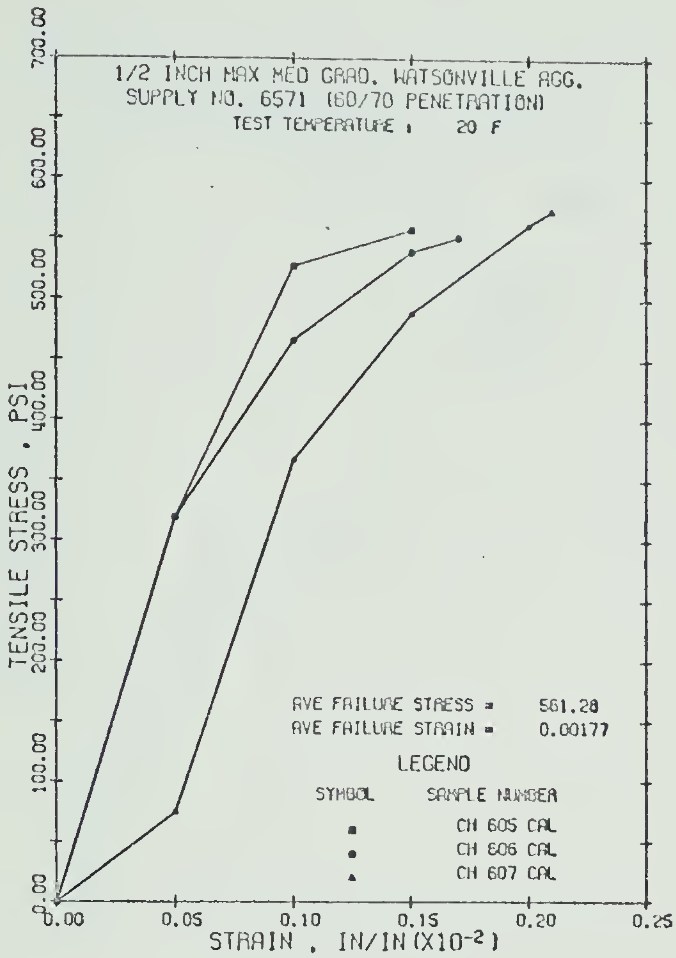


FIG. C6(a)

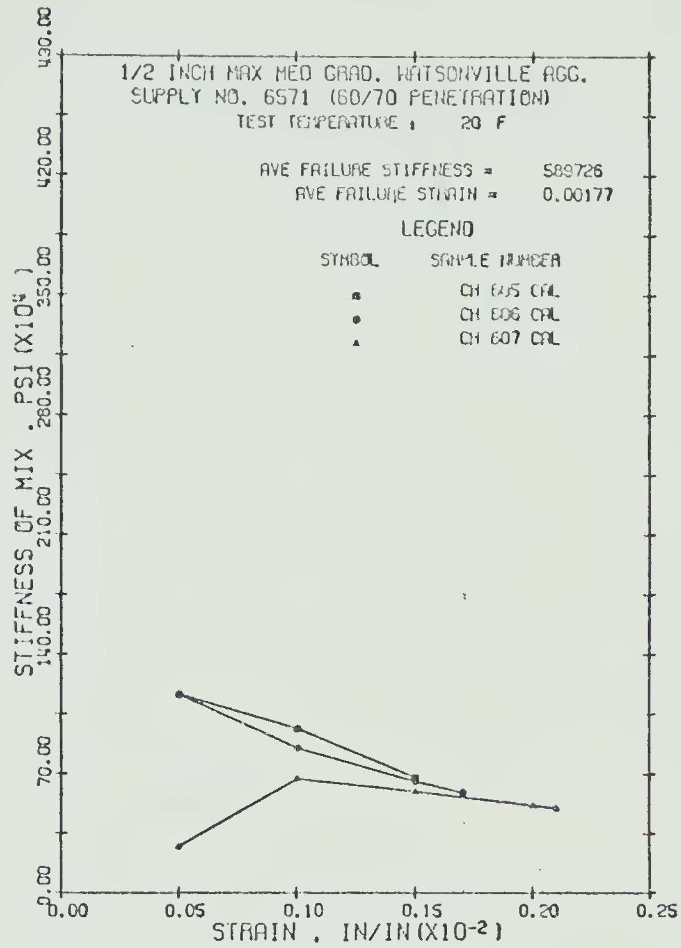


FIG. C6(b)

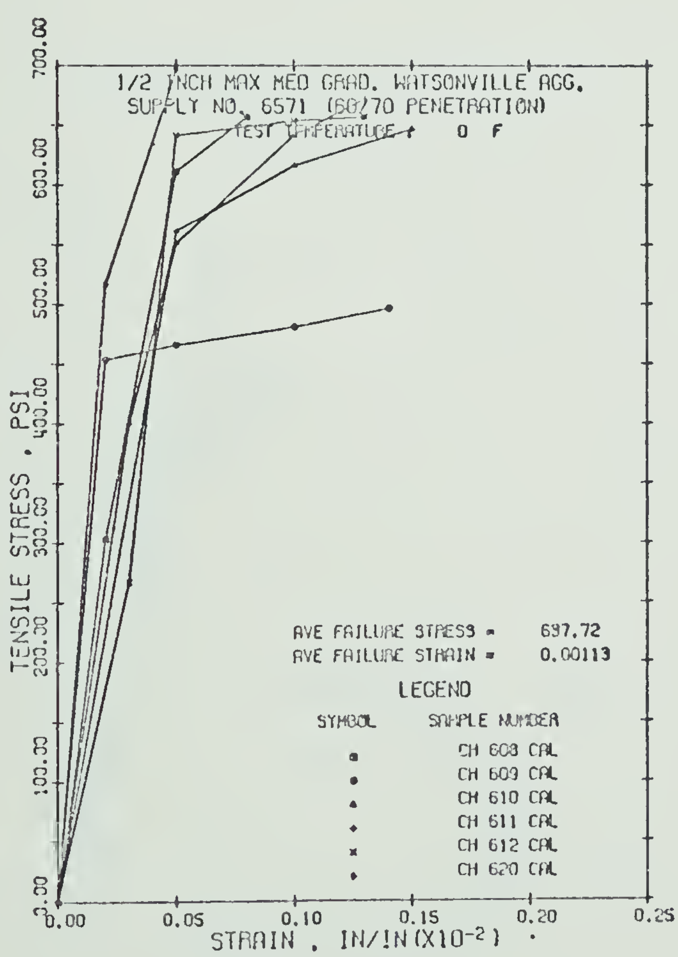


FIG. C6(c)

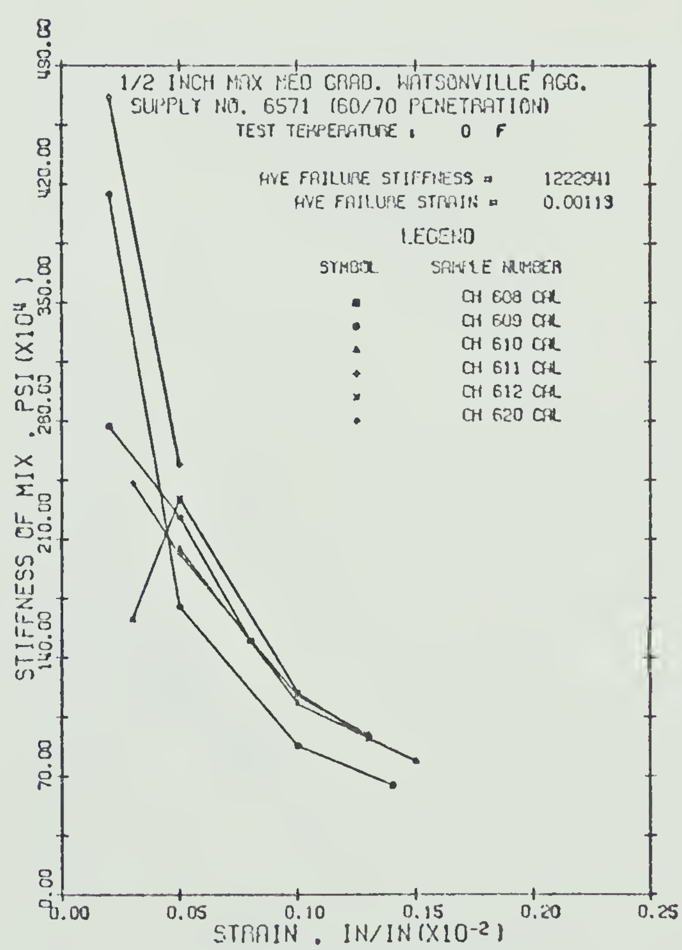


FIG. C6(d)

FIGURE C6: Chevron (60/70 Penetration)

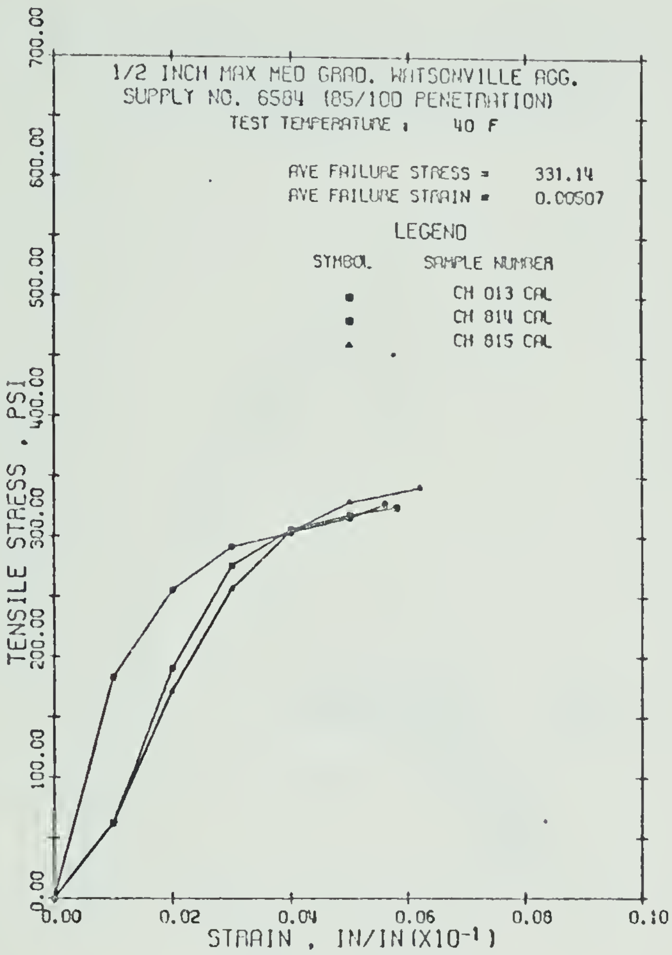


FIG. C7(a)

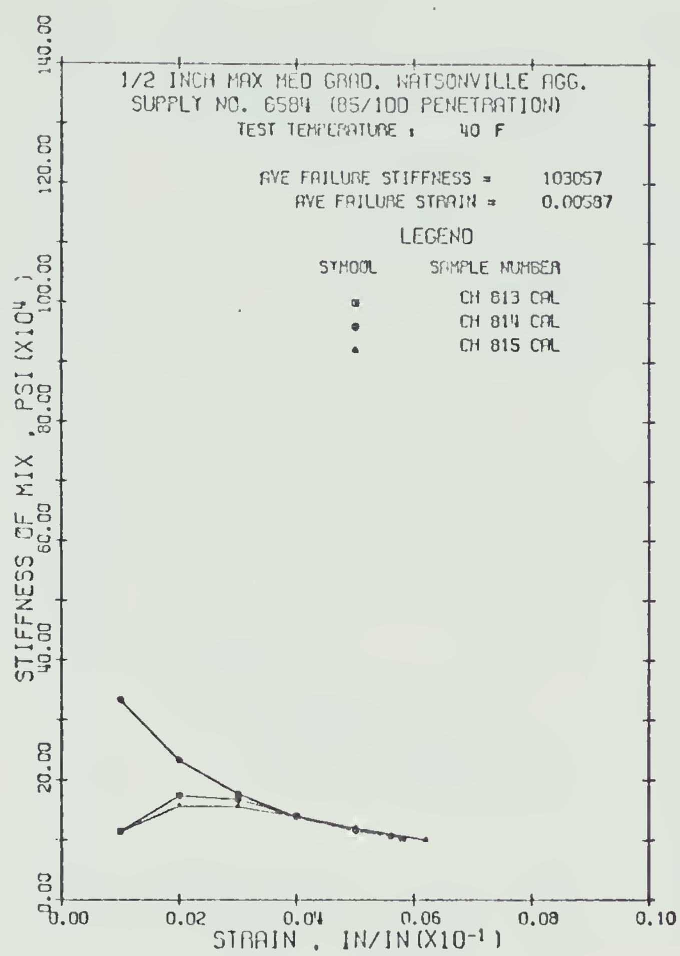


FIG. C7(b)

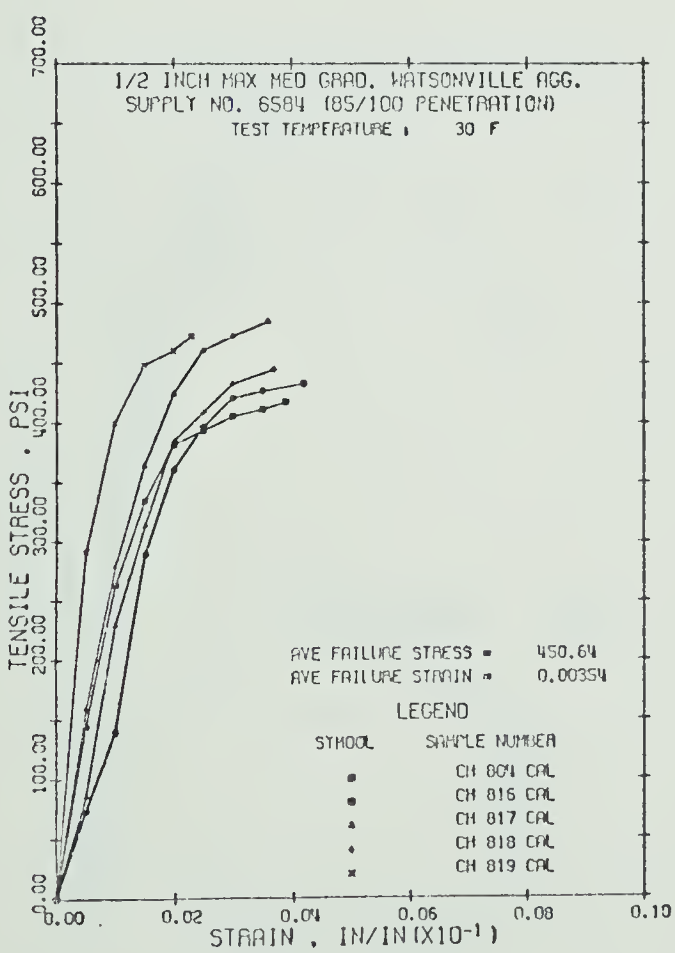


FIG. C7(c)

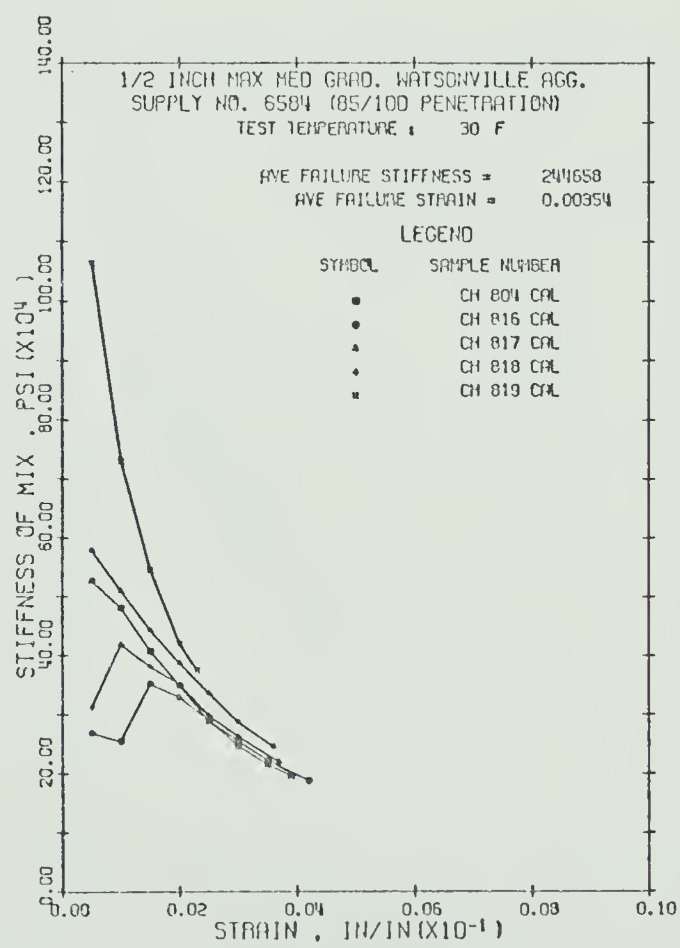


FIG. C7(d)

FIGURE C7: Chevron (85/100 Penetration)

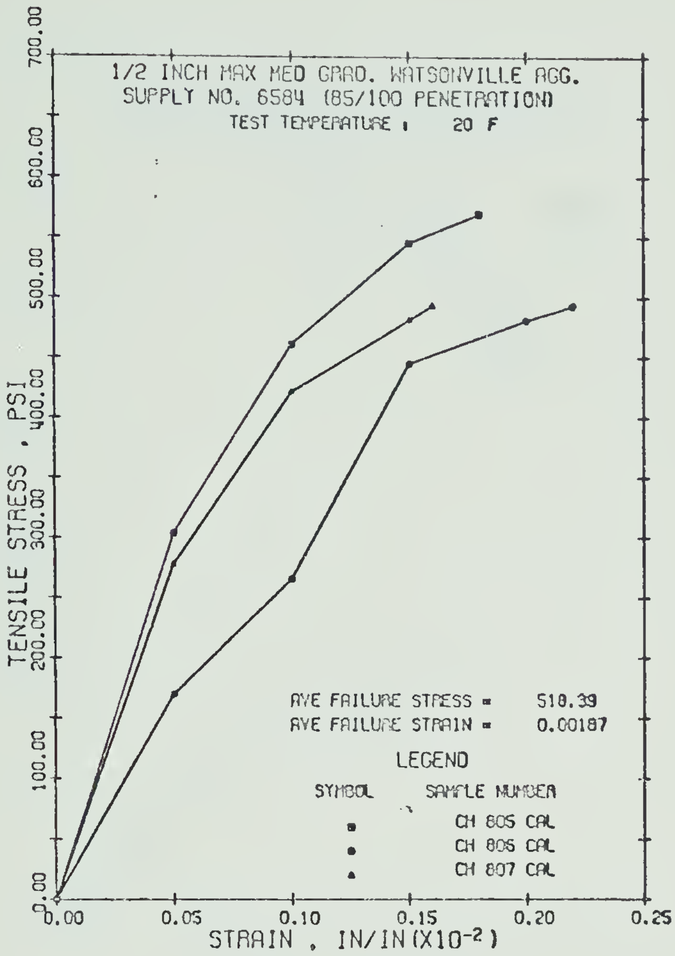


FIG. C8(a)

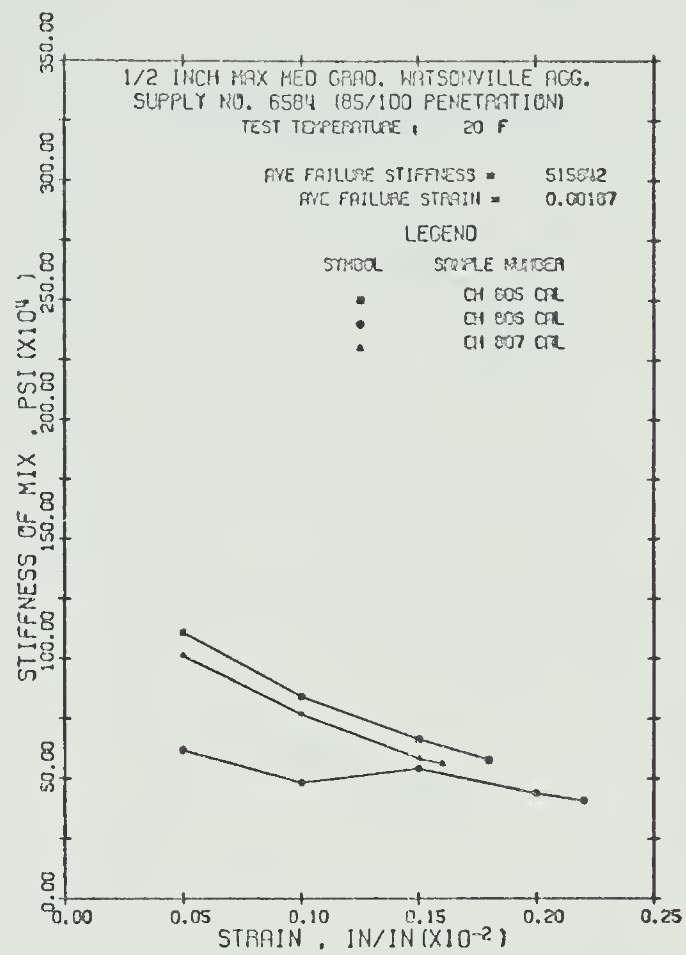


FIG. C8(b)

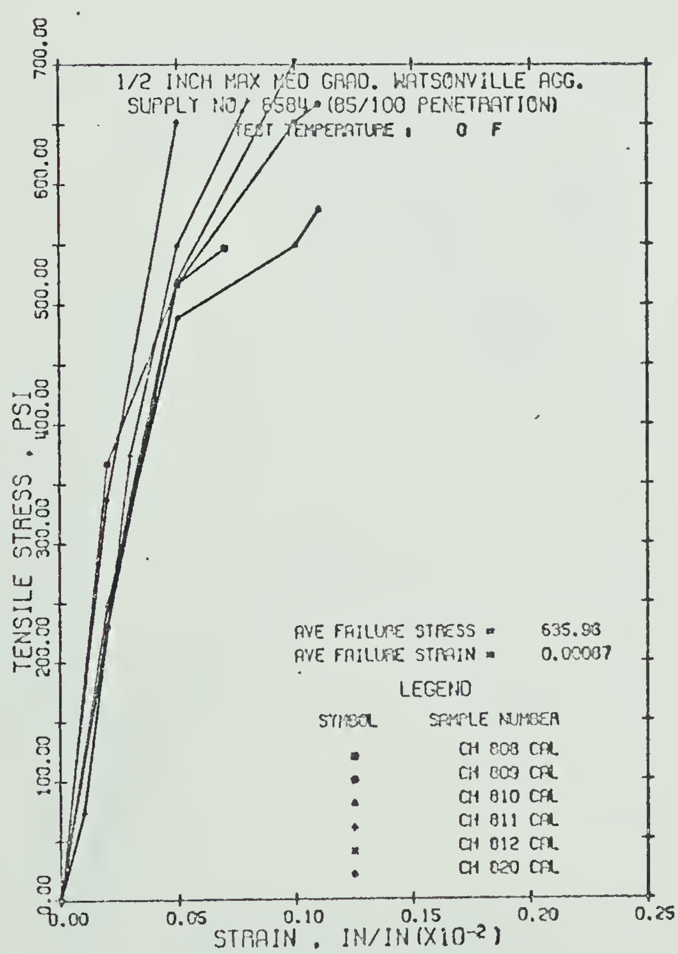


FIG. C8(c)

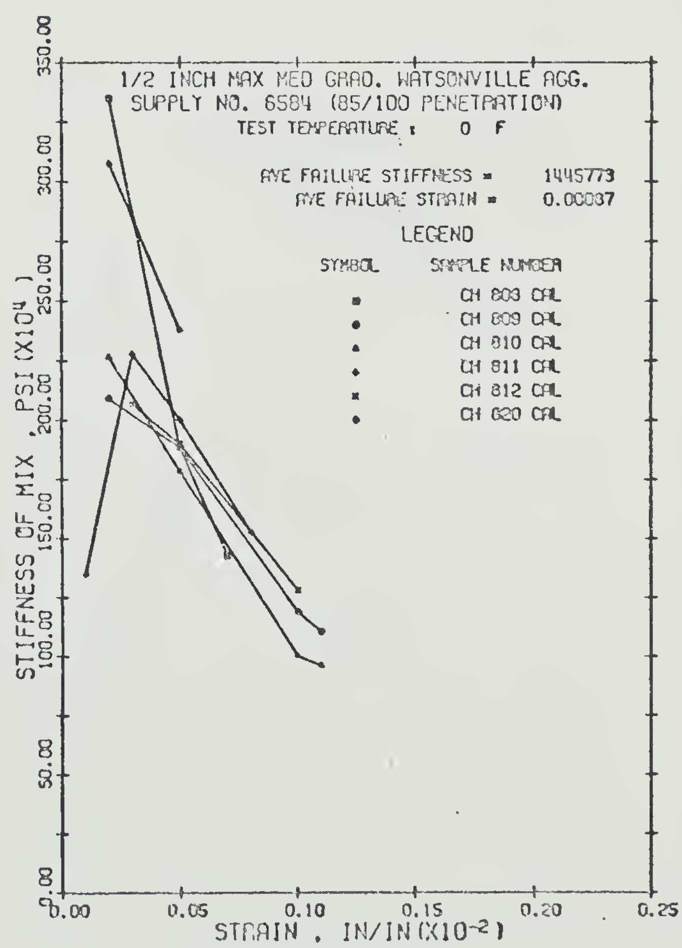


FIG. C8(d)

FIGURE C8: Chevron (85/100 Penetration)

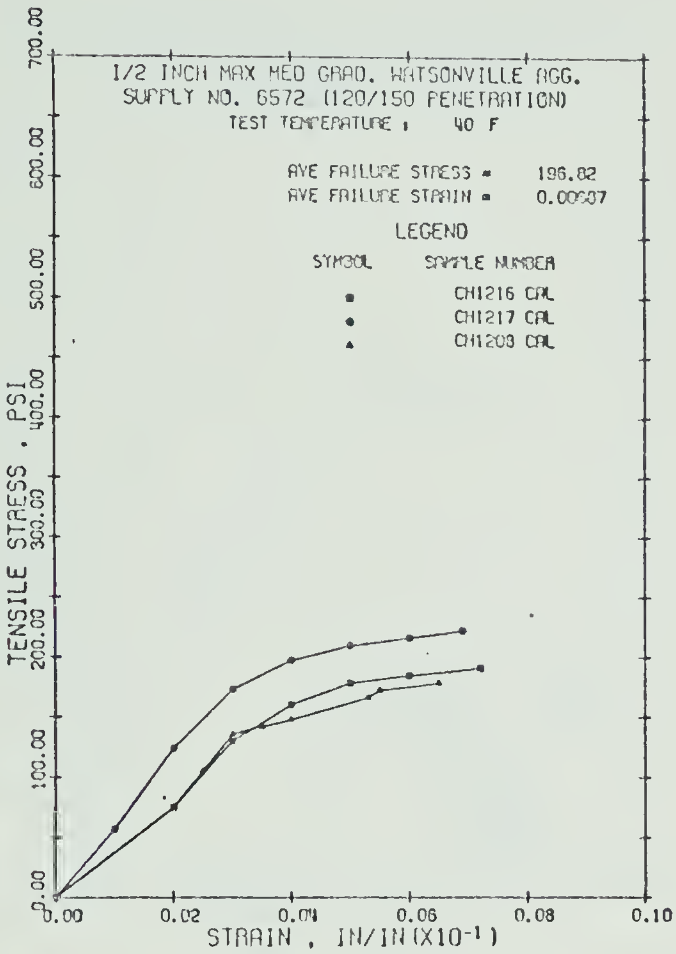


FIG. C9(a)

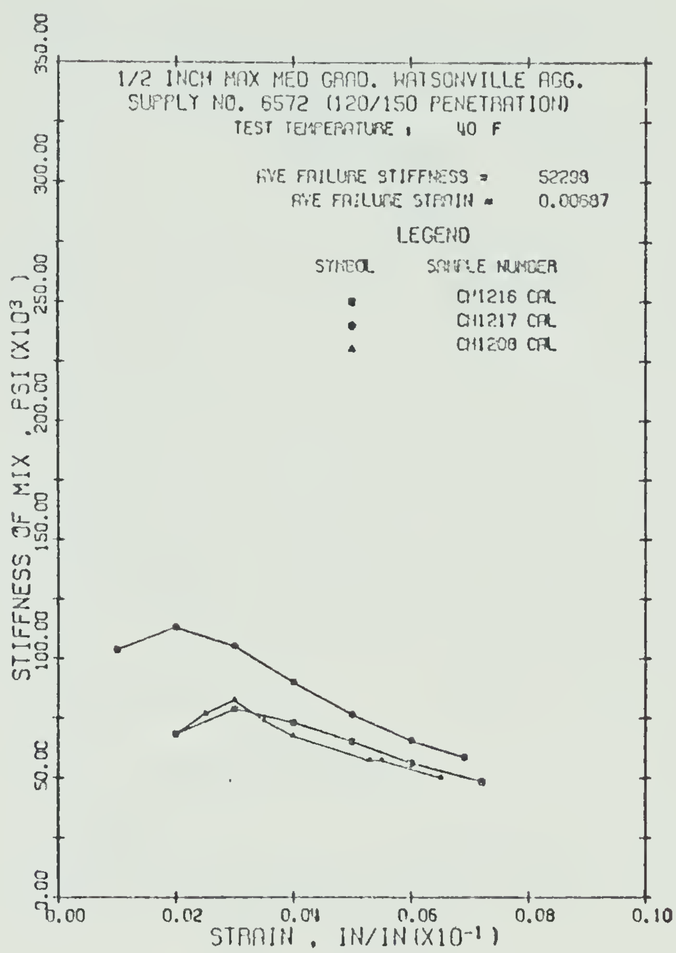


FIG. C9(b)

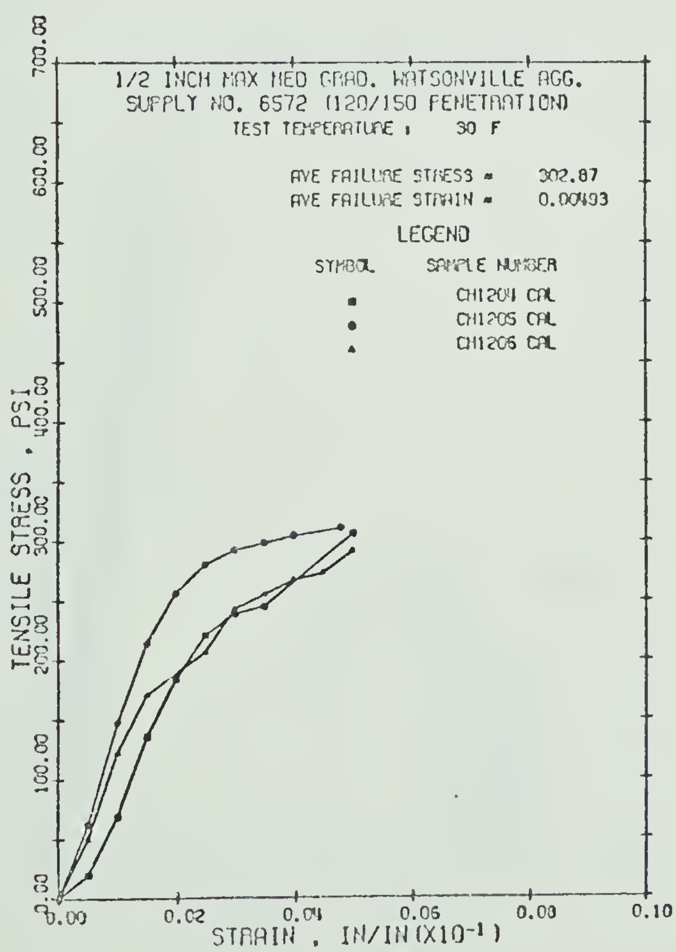


FIG. C9(c)

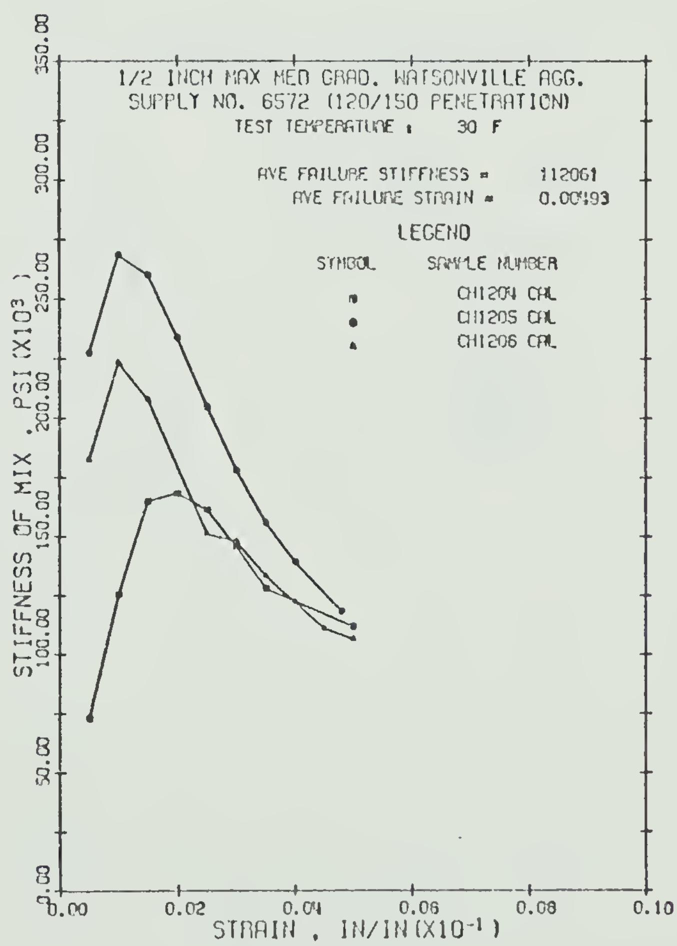


FIG. C9(d)

FIGURE C9: Chevron (120/150 Penetration)

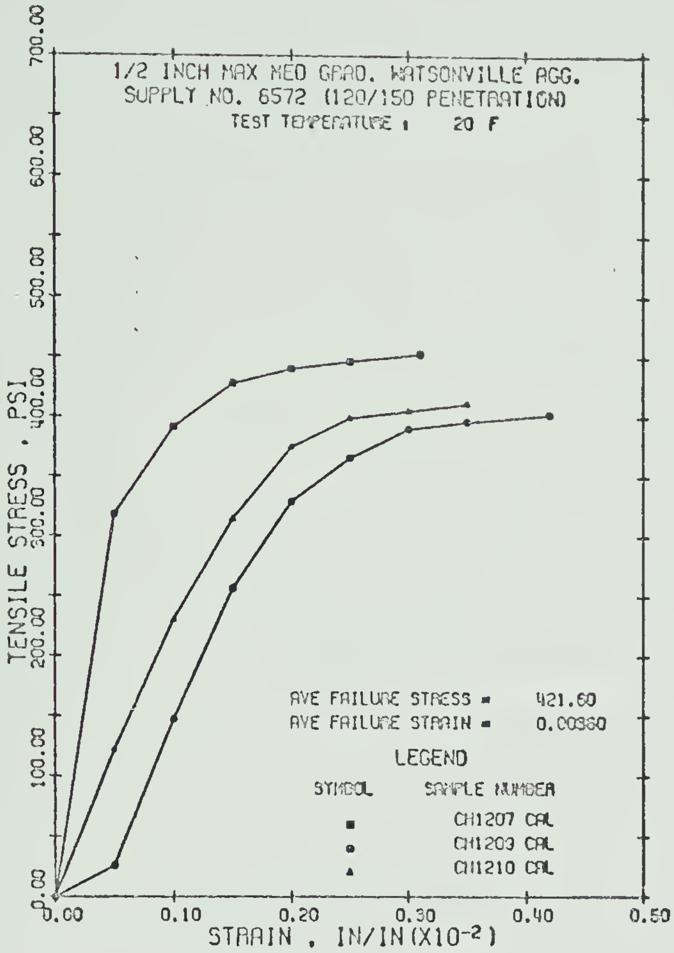


FIG. C10(a)

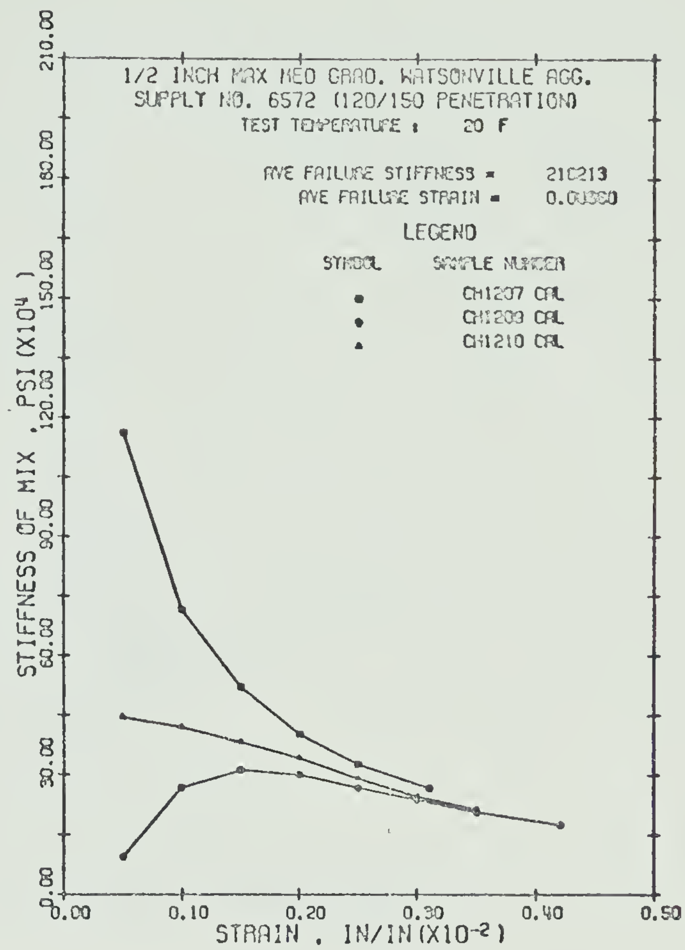


FIG. C10(b)

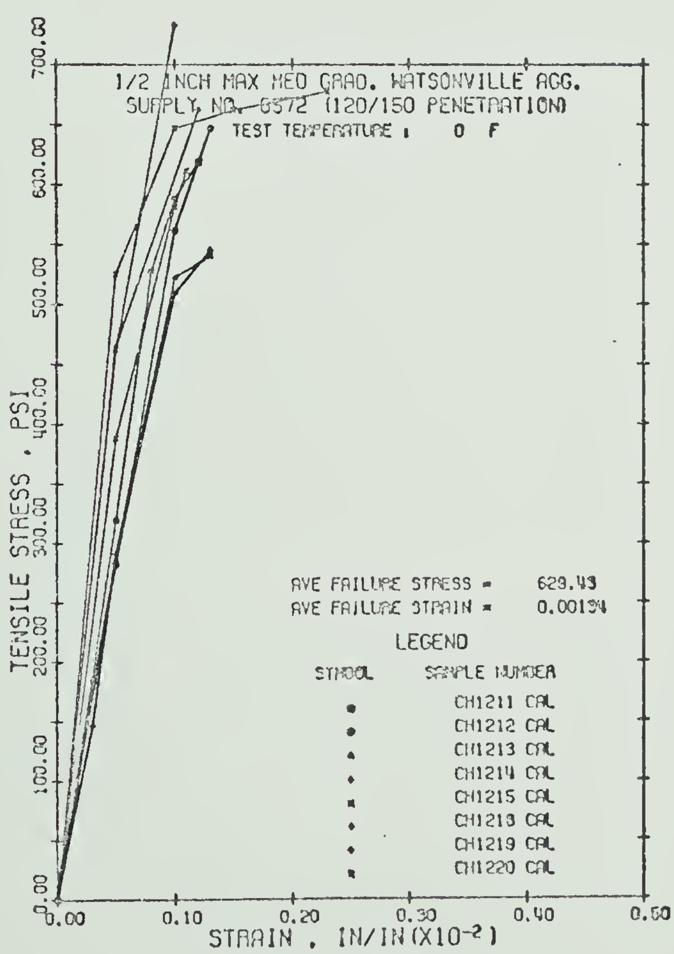


FIG. C10(c)

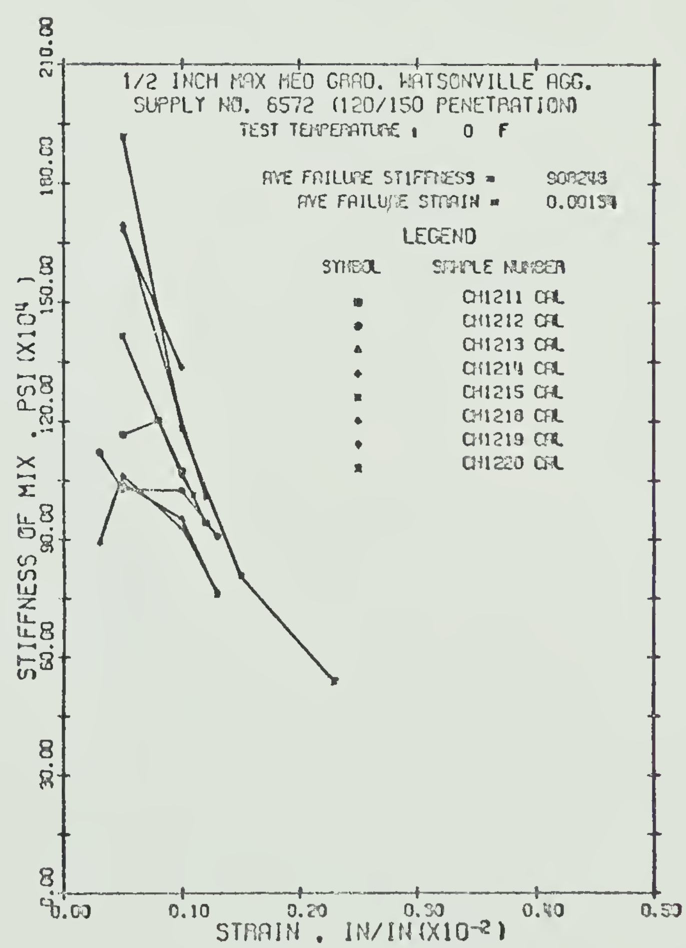


FIG. C10(d)

FIGURE C10: Chevron (120/150 Penetration)

APPENDIX D

COMPUTER PLOTS OF TENSILE STRESS VS. STRAIN
AND STIFFNESS OF MIX VS. STRAIN FOR
WATSONVILLE AGGREGATE
CALIFORNIA AND ALBERTA ASPHALTS
VARIOUS MECHANICAL IMPACT COMPACTIVE EFFORTS

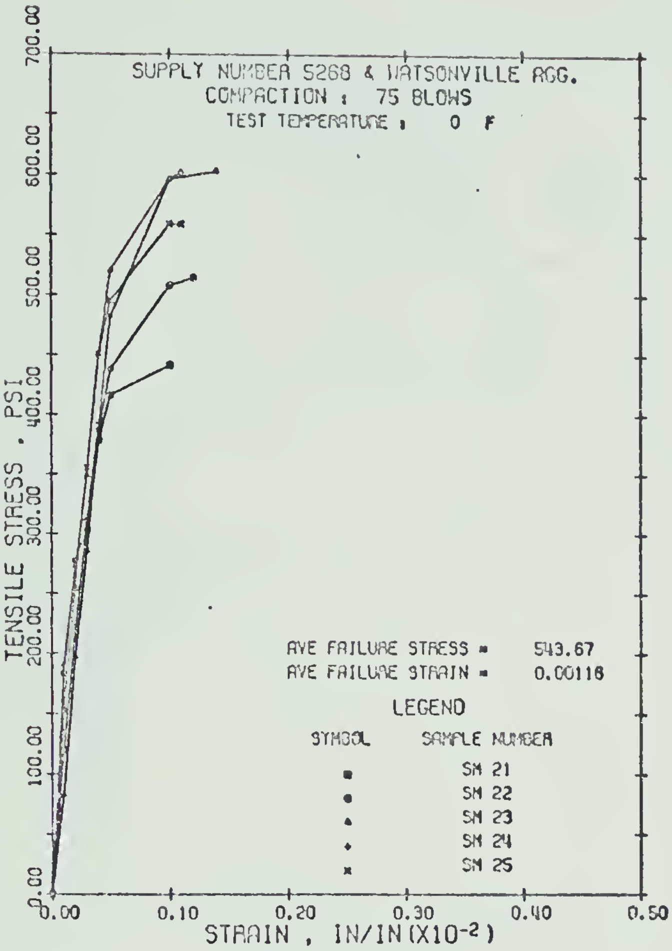


FIG. D1(a)

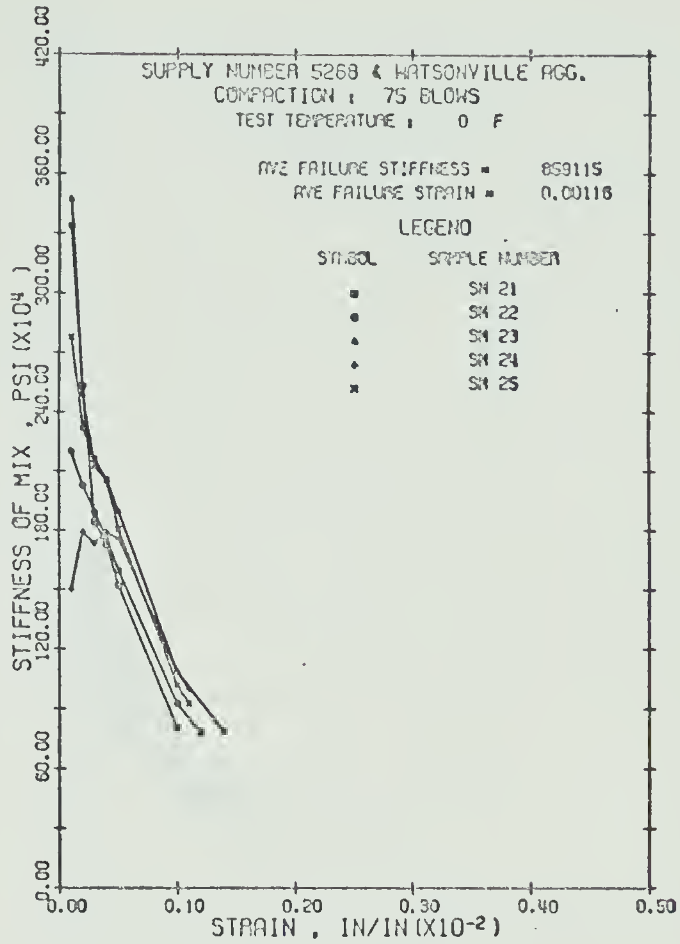


FIG. D1(b)

FIGURE D1: Santa Maria (85/100 Penetration) 75 Blows

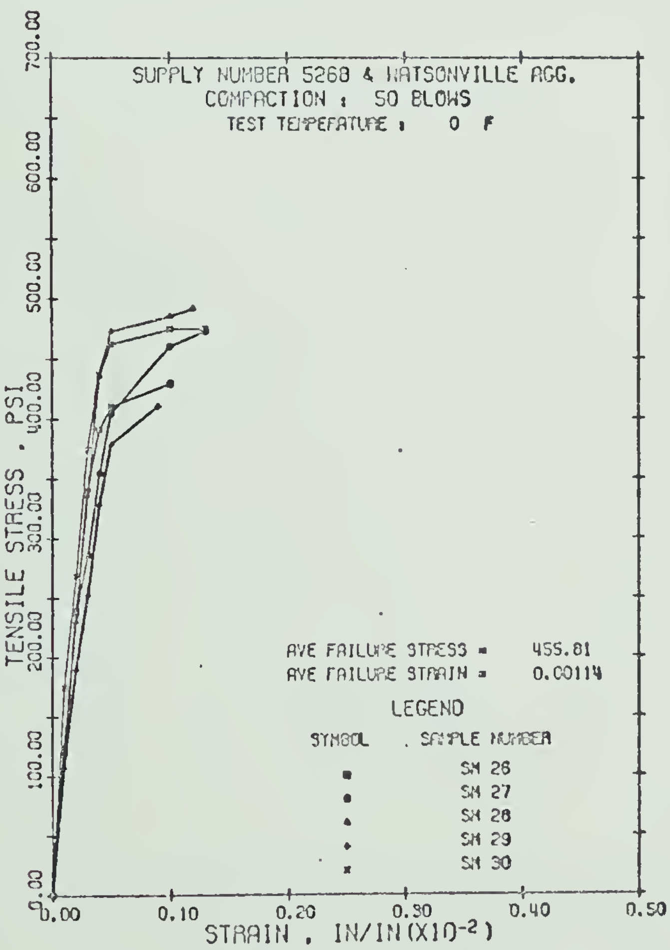


FIG. D2(a)

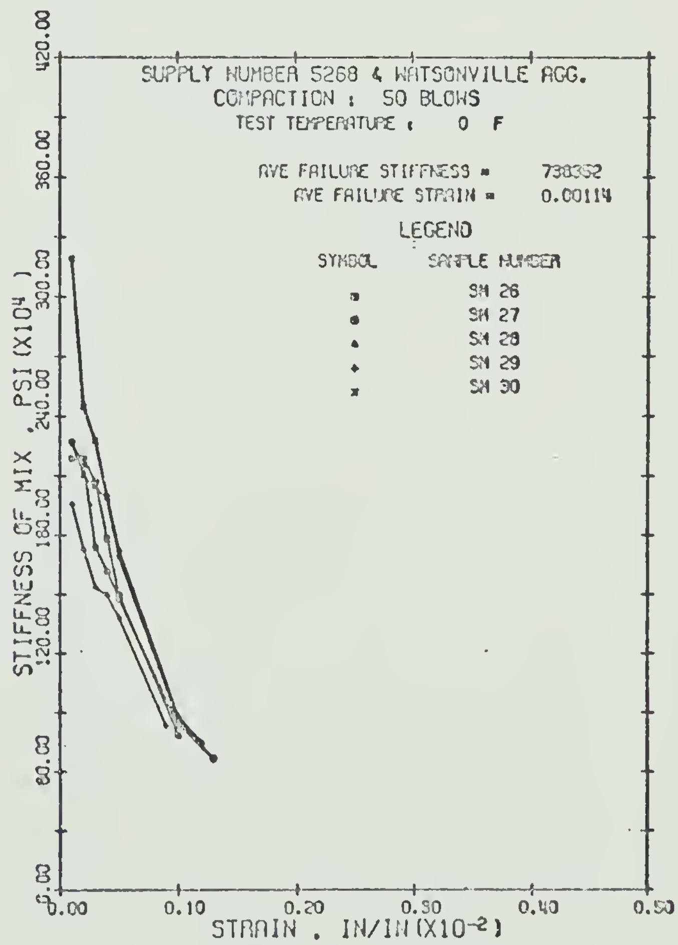


FIG. D2(b)

FIGURE D2: Santa Maria (85/100 Penetration) 50 Blows

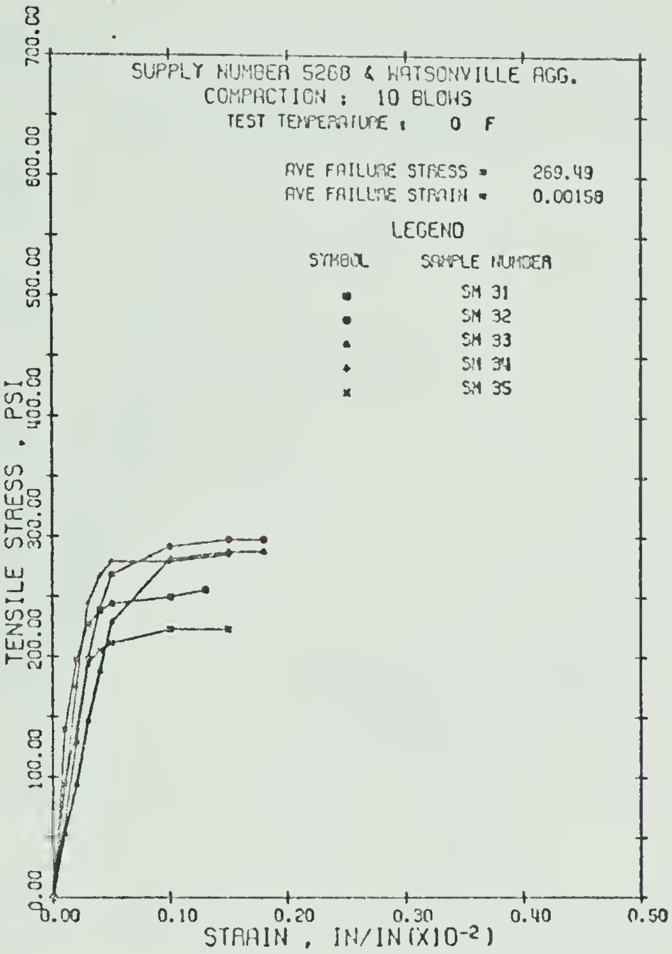


FIG. D3(a)

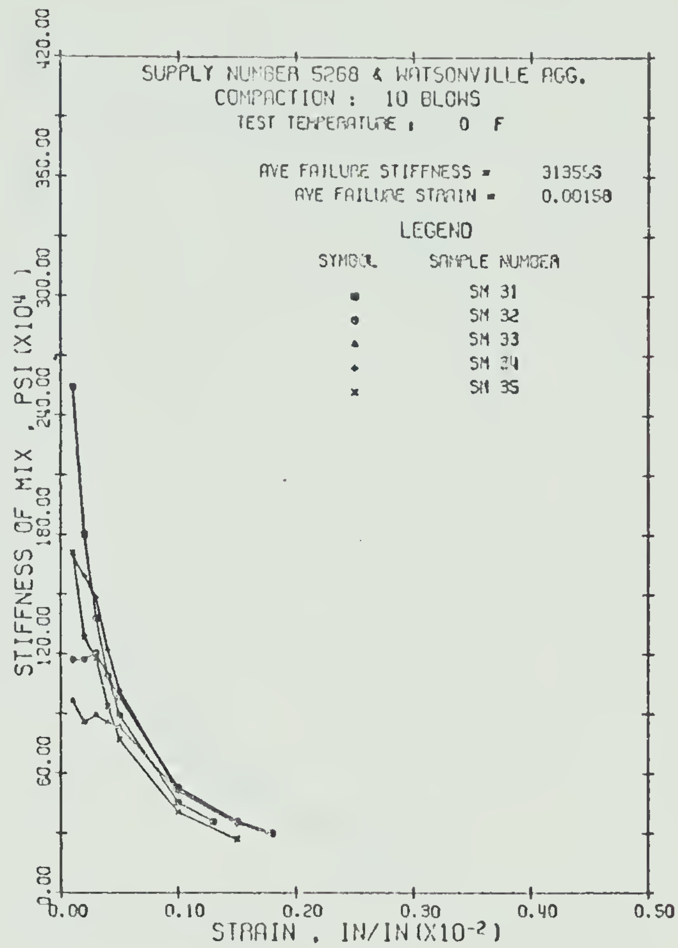


FIG. D3(b)

FIGURE D3: Santa Maria (85/100 Penetration) 10 Blows

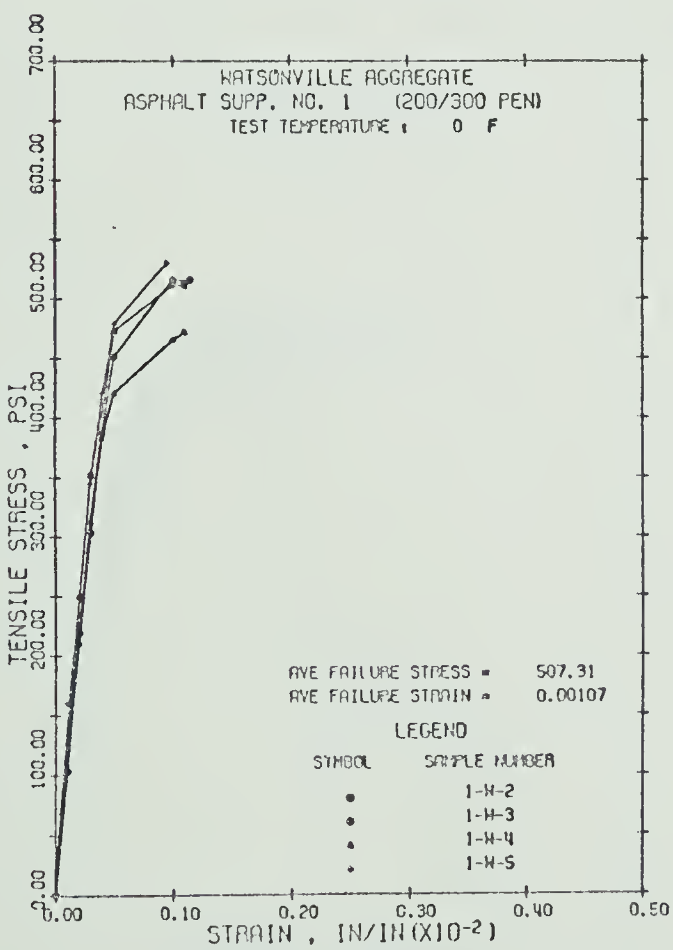


FIG. D4(a)

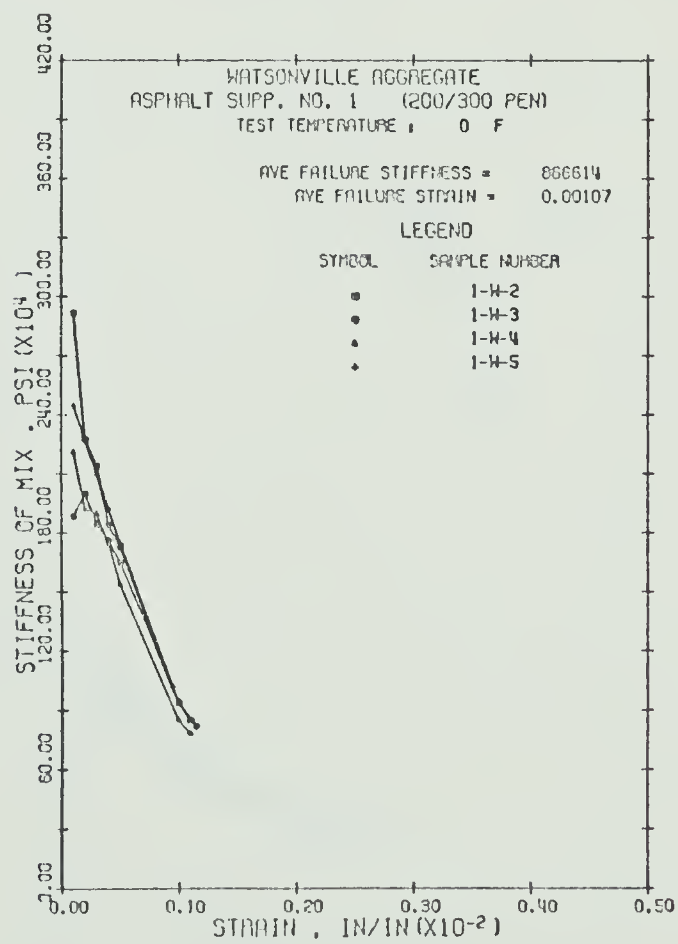


FIG. D4(b)

FIGURE D4: Alberta Supply No. 1 - 75 Blows

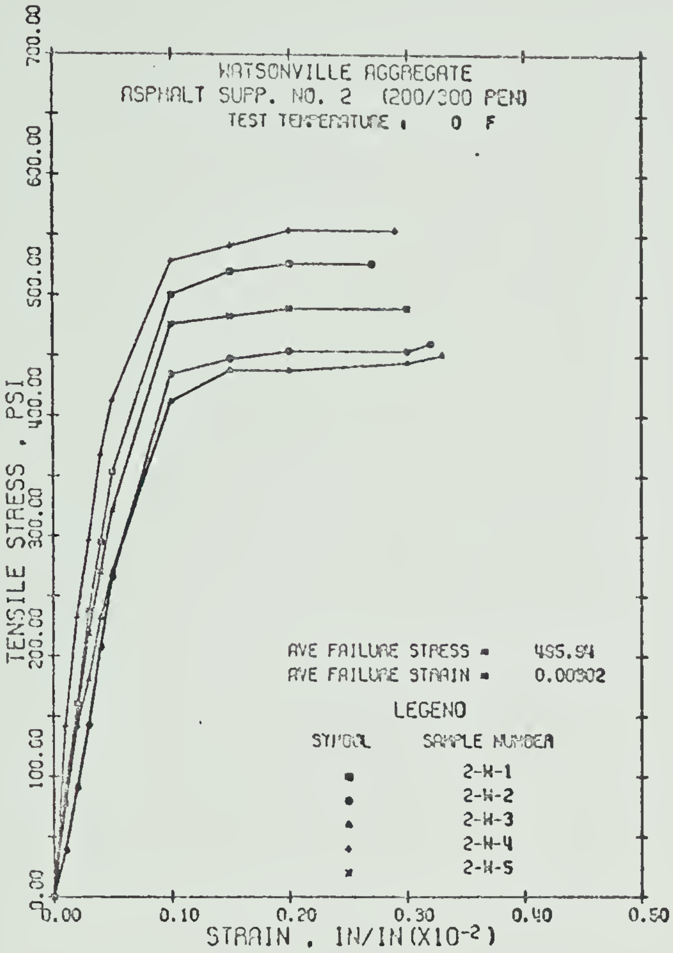


FIG. D5(a)

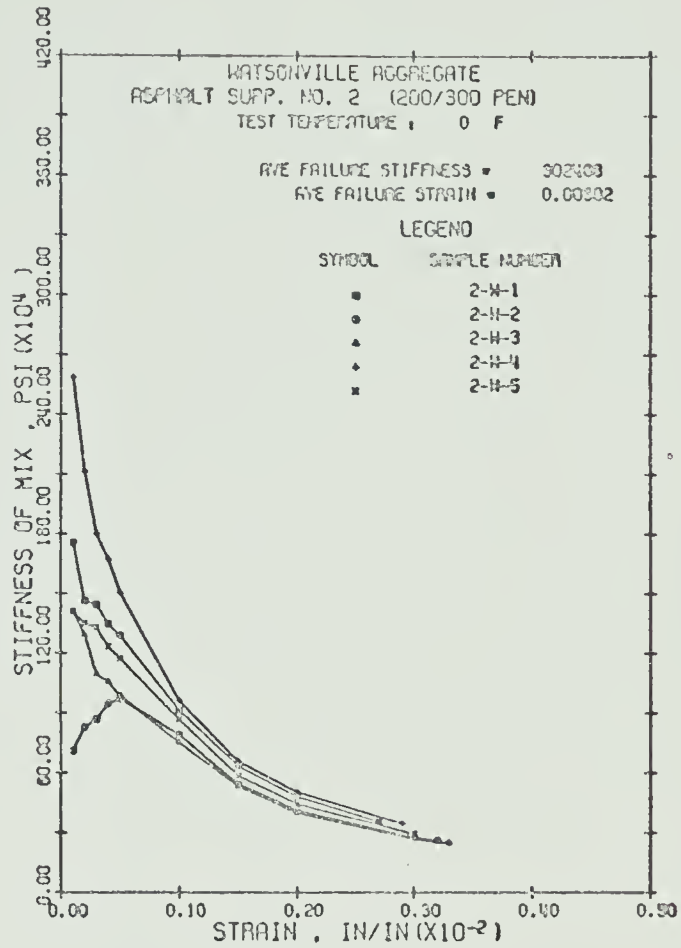


FIG. D5(b)

FIGURE D5: Alberta Supply No. 2 - 75 Blows

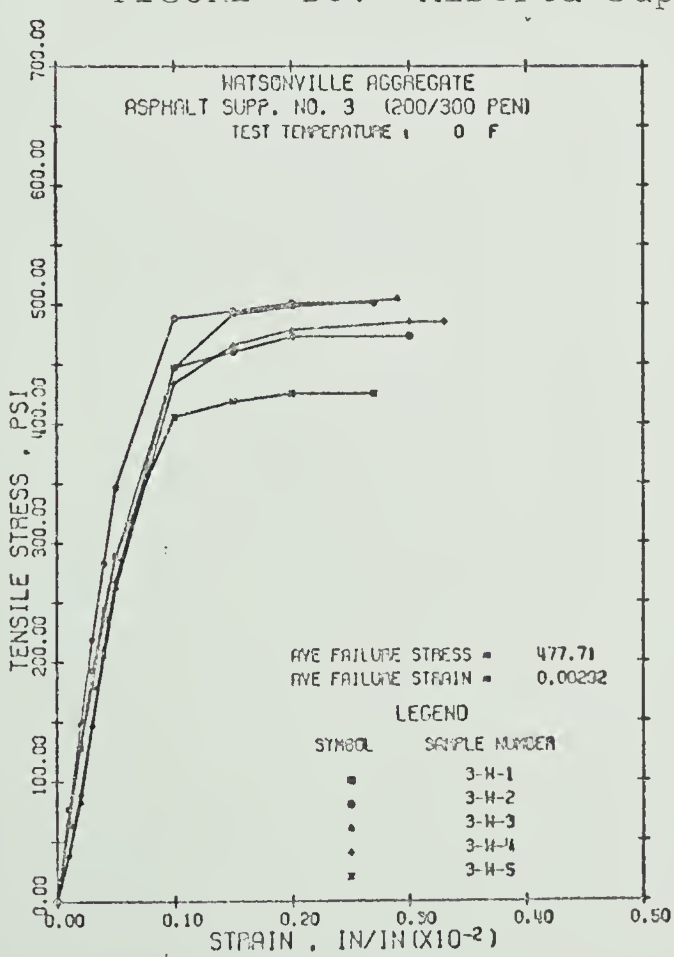


FIG. D6(a)

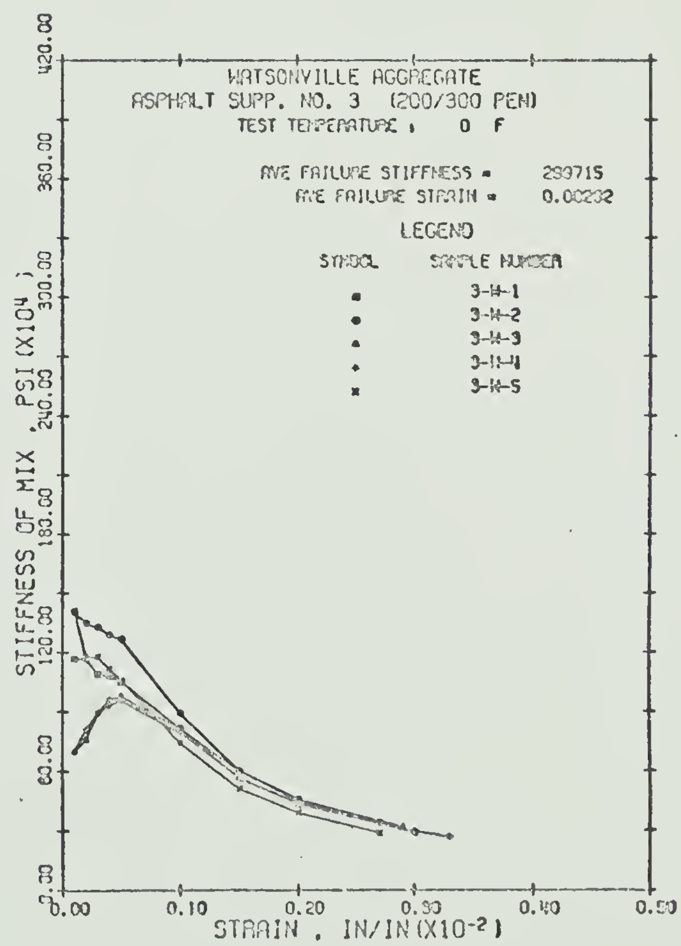


FIG. D6(b)

FIGURE D6: Alberta Supply No. 3 - 75 Blows